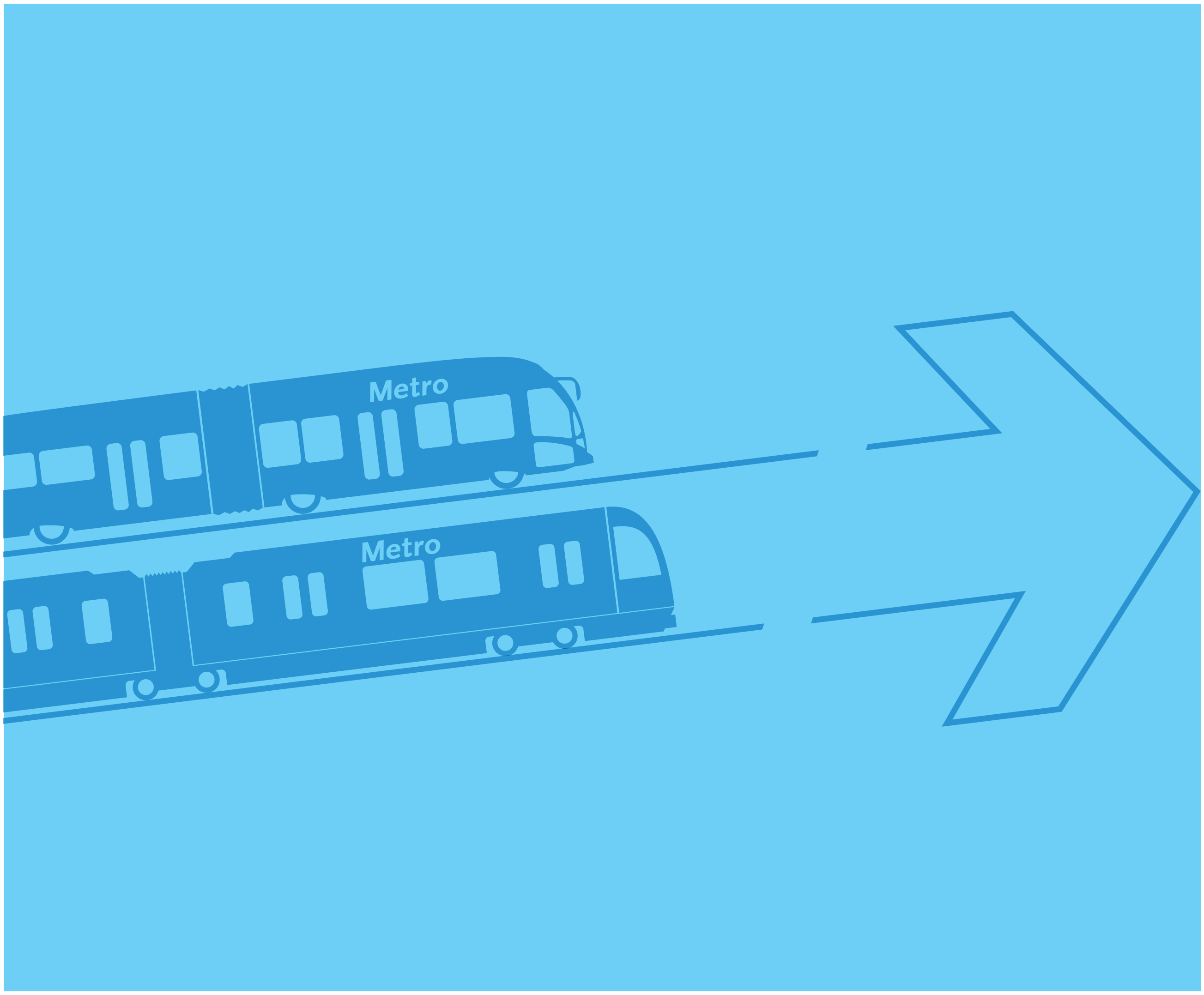
BUS AND RAIL FLEET SYSTEMS STRATEGIC PLAN



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Metro

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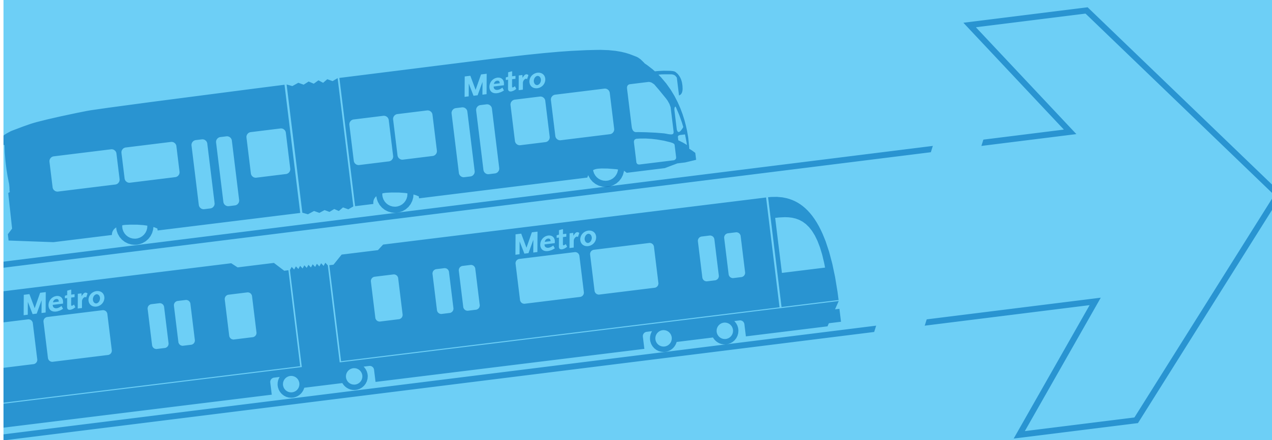


BUS AND RAIL FLEET SYSTEMS STRATEGIC PLAN

EXECUTIVE SUMMARY

PROJECT PURPOSE: This Bus and Rail Fleet System Strategic Plan provides the Los Angeles County Metropolitan Transportation Authority (Metro) with a clear, actionable set of recommended projects to best support the needs of the agency's fleet technology program, including the need to strengthen its customer-facing tools and information. Overall, the Strategic Plan represents a logical and phased blueprint for fleet and communications systems replacements to maintain them in a state of good repair and upgrades to significantly enhance functional and operational capabilities, while providing Metro with forward-looking technology solutions. Recommended projects have been mapped onto timelines with dependencies between projects identified along with overall Rough Order Magnitude (ROM) costs broken down by primary program areas.

OVERVIEW & BACKGROUND

The primary goals of the Strategic Plan focus on improving Metro's operational efficiency and reliability along with customer satisfaction. These goals are supported by a series of fleet and communications systems upgrades and implementations recommended as part of the program projects and actions in the Plan. The recommended projects are focused on providing enhanced functionality, overcoming current system and communications constraints, and replacing key fleet systems nearing the end of their useful life. As an example, one of the many impetuses for the development of the Plan were the current issues with certain elements of the Advanced Transportation Management System (ATMS) that have become difficult to maintain, and replace as they are approaching the end of the product's life.

In order to define a set of achievable projects that support Metro's overall bus and rail fleet systems program, this project began with a series of needs assessment workshops and interviews to identify current bus and rail needs, assess existing fleet and communications systems, and identify on-going and planned program systems development efforts. The findings were then summarized in an interactive workshop followed by the Technical Memorandum 1: Needs Assessment and Technical Memorandum 2: Communications Assessment.

GOALS OF THE PROGRAM

The primary goals of the Strategic Plan projects include the following:

- Provide reliable and robust voice and data communications for bus and rail.
- Update/replacement of bus CAD system nearing end of life.
- Provide CAD tools for rail.
- Define modern, updated, and flexible architecture for on-board systems.
- Provide improved, robust, integrated traveler information systems.
- Support real-time access to onboard video
- Improve interfaces for SCADA systems
- Improve IT systems for bus and rail yards

Following completion of the needs assessment, an alternatives assessment was completed evaluating a series of fleet and communications alternatives identified to meet the broad range of ITS-related needs. Evaluation criteria were developed, which used a common approach and considered the technical ability of each alternative to meet identified needs, benefits, strengths, weaknesses, opportunities, threats, capital and O&M costs, implementation timelines, risks associated with each alternative, benchmarking of where each alternative may have been implemented by other transit agencies, and whether each alternative would require significant updating to work as technology advances (i.e., “future proofing”). The highest scoring alternatives were reviewed with key Metro stakeholders in an interactive workshop, followed by a technical memorandum, and then carried forward as the recommended projects for this Plan. The resulting program of projects outlined in this Plan represent the highest scoring and selected alternatives from the earlier analysis efforts. At each stage, a broad group of stakeholders from Metro departments including bus operations, rail operations, ITS, maintenance, communications, risk management, security, and others were involved in the evaluation and reporting of results.

STRATEGIC PLAN RECOMMENDATIONS

Several recommended technology solutions supporting improvements to Metro’s operating and business environments—and importantly, customer experience—have been identified over the course of this project. These solutions make up an overall technology program for Metro to implement over the next fifteen years in a coordinated and phased approach to replace and update aging ITS systems and improve customer-facing systems. The Strategic Plan also takes into consideration both current and planned Metro projects.

The recommended projects presented in this Plan have been grouped into two main categories: foundational and supporting elements. **Foundational projects** improve the backbone of Metro’s fleet technology systems that will have the most significant impact on the improvement of operations, address the most needs, and have the greatest impact on other solutions. **Supporting projects** build upon these foundational elements to offer Metro and its customers a fully realized Strategic Plan. It is anticipated that timelines in the Strategic Plan may shift based on funding availability and changing priorities, but the relationships between the projects, the overall cost estimates, and the project scope elements will remain the same.

STRATEGIC PLAN RECOMMENDATIONS:

FOUNDATIONAL ELEMENTS

The following recommended projects are considered “foundational elements” for Metro to achieve the goals of the Strategic Plan and to meet the key needs identified. These foundational elements include:

- **Communications system improvements** necessary to successfully implement several of the recommended projects and/or achieve the improvements envisioned
- **On-board architecture improvements** necessary to best leverage the communications system and ATMS II improvements and position the agency to be prepared for implementation of emerging and future technologies
- **ATMS II Bus and Rail** implementation will serve as a backbone for all other bus and rail fleet systems, provide a reliable source of bus and rail fleet data, and improve operational efficiency through the use of new and improved tools that are currently available in the technology market.

Communications Recommendations

During the initial needs assessment phase, the existing conditions, technology trends, and telecommunications needs were documented as inputs to this Strategic Plan. While the recently upgraded voice radio system for rail was deemed sufficient, there are significant issues with the current capabilities of Metro’s mobile data communications for the bus fleet and the age of the radio equipment for the voice and data radio system. The needs assessment also identified a significant need for the establishment of data communications for the rail fleet to improve both operations and the accuracy of real-time rail predictions. The key communications recommendations are described in the table below.

COMMUNICATIONS RECOMMENDED PROJECTS	LTE DATA CELL · VOICE (VOIP) · VOICE RADIO
C.2 **Bus Data - Establish cellular service for Bus Fleet** **C.5** **Rail Data – Establish cellular service for Rail Fleet**	Metro would deploy a single, flexible, high-bandwidth data solution for both bus and rail fleets. The data solution would utilize a high-speed, broadband data communications system. A cellular data system would offer better coverage and greater capacity than a traditional radio system and enable improved arrival predictions, video streaming, and real-time farebox communications. The cellular provider would maintain the network, reducing Metro’s ongoing O&M costs. In addition, the cellular data network could be implemented quickly. Drive tests should be conducted to determine which provider has the best coverage. LA-RICS LTE should also be considered as one of the options. By implementing a cellular data system, Metro would avoid the high costs to repair a breakdown of the current aging ATMS data radio system and to find spares. This solution is being widely deployed by transit agencies across the US. Projects C.2 and C.5 must be largely complete before Metro can leverage the improved data communications platform in order to to provide the vehicle location reporting improvements under project A.5 necessary to support the recommended supporting systems projects.
C.3 **Bus Voice – Establish VoIP for Bus Fleet (with Radio Backup)**	Metro would replace the entire current bus voice radio system with a new Voice-over-Internet Protocol (VoIP) system. This system would most likely be replaced as part of a larger ATMS replacement effort, as the Computer Aided Dispatch vendor selected through an ATMS II procurement would need to provide the integration and management of the VoIP solution to be controlled by the Computer Aided Dispatch/ Automatic Vehicle Location (CAD/AVL) system. The VoIP solution would utilize a high-speed, broadband data communications system and would offer better coverage and greater capacity than a traditional radio system. The cellular provider would maintain the network, reducing Metro’s ongoing O&M costs. VoIP could also be implemented quickly. By implementing VoIP, Metro would avoid the high costs to repair a breakdown of the current aging ATMS voice radio system and to find spares. This technology is currently being deployed by a growing set of transit agencies worldwide and is available through a number of technology providers. The current Metro bus voice system could be modified and retained as a fallback option in the event of emergencies.

A key recommended component of the onboard communication system is a Mobile Gateway Router (MGR), which is included as part of the recommended on-board architecture in this Plan. The MGR will enable the utilization of multiple communications paths, including cellular data (from multiple carriers), WiFi, LTE, LMR, and other networks to build redundancy into the implemented communication solution. Other communications related projects identified in the Strategic Plan include expansion of the Icom rail voice radio system to support future rail system expansions and modification of the radio system in the Red Line tunnels to include LA-RICS LMR channels when the LA County Sheriff migrates onto the LA-RICS LMR system. Finally, the communications plan should be revisited when the commercial cellular providers role out 5G service and again when they implement 6G service.

ATMS II Bus and Rail Recommendations

The Task 1 needs assessment identified significant needs related to ATMS, which is the CAD tool currently used by Metro to manage bus fleet operations. ATMS was implemented in 2004 and the on-board ATMS components and other subsystems are outdated, nearing end of life, and are in need of replacement/upgrade. In addition, significant needs were noted to enhance, update, supplement, and/or replace the dispatching and operations control functionality of ATMS. In some cases, this simply involved streamlined reporting and new methods of more rapidly and effectively getting information from ATMS to other systems. Needs were also identified for ATMS to better support multi-modal incidents (e.g. ability to coordinate bus bridges for rail operations). In short, enhancements are needed to get the right data to the right people at the right time.

The Task 1 needs assessment also identified significant needs for CAD tools for rail fleet operations. Currently, rail controllers utilize the SCADA system to monitor train locations and utilize M3 to store incident information. Since there is no mobile data communication system, controllers can only communicate with operators via the voice radio system and rail vehicles do not report their vehicle location. Needs were identified for rail CAD tools to improve the method to log incidents, provide a message tool for communications between controllers and operators, implement data communications to and from the rail vehicles, improve the efficiency of data collection from the rail vehicles, and improve coordination of activities with bus operations. Including AVL capability with a CAD system for rail operations would help meet the need to improve the reporting of train location information and arrival predictions for customers.

The recommended technology program for Metro presented in this Plan, therefore, includes a procurement of new CAD/AVL system called ATMS II to replace ATMS. ATMS II would support both bus and rail operations and would improve the coordination between the bus and rail operations when there are situations that involve both operations such as bus bridges. Implementing a single CAD/AVL system for both bus and rail operations would be more cost effective than implementing separate CAD systems for each. For these reasons, a number of transit agencies have implemented or are implementing joint CAD/AVL systems for their bus and rail fleets. The following table provides an overview of the recommended sequenced ATMS replacement/upgrade projects for bus and rail.

ATMS II FOR BUS AND RAIL RECOMMENDED PROJECTS

A.1 + A.2
Prepare/Budget for ATMS II for Bus and Rail with Consultant Support and Procure Consultant Support

The first step in the open procurement for the replacement of ATMS project will be internal Metro work to obtain approval for the ATMS II project budget and to issue a request for proposals (RFP) for consultant services for the requirements definition, design, development of a vendor RFP, and implementation support. By engaging consultant support, Metro staff will be better able to remain focused on their primary objectives of enhancing service delivery and improving customer experience.

A.3 + A.4
Prepare for ATMS II Procurement for Bus and Rail

Utilizing the consultants engaged under A.2, Metro will develop a complete RFP package for an open procurement for the replacement of the ATMS system. It is anticipated this procurement will include the ATMS II central system, work stations, voice and data communications system replacements for bus and rail as described in the Communications Plan, and most, if not all, of the on-board architecture elements for bus and rail described below. By packaging these elements together, Metro will benefit from cost savings when several projects in the Strategic Plan are implemented in conjunction as one project. Metro may also benefit from reduced O&M costs when several projects are implemented as one.

A.5
ATMS II Implementation for Bus and Rail

Metro implements the new ATMS II solution in two phases, starting with the bus fleet, then implementing ATMS II for the rail fleet during a second phase. ATMS II will replace the current ATMS system that is nearing end of life. ATMS II will utilize state-of-the-art technology to enable more efficient operations, improved voice and data communications, improved accuracy in vehicle location reporting and time of arrival predictions, and improved CAD tools for Metro staff, which will allow them to more effectively manage incidents and to disseminate service changes and disruptions information to Metro's ridership. Upgrade of the ATMS onboard components will enable Metro to migrate to a modern onboard architecture that will allow for flexibility in the communication systems used and flexibility in the addition of new onboard components.

It is envisioned the ATMS II implementation will include the replacement of the ATMS bus voice and data communication systems and the implementation of the rail data communication system, along with the recommended emerging trends on-board architecture described in the following section.

Project A.5 is a foundational project and must be underway, along with substantial completion of projects C.2 and C.5, before most of the supporting systems projects can be successfully implemented.

On-board Architecture Recommendations

The ATMS II implementation presents a unique opportunity for Metro to establish ITS on-board architectures for the bus and rail fleets that will enable the agency to more easily replace and upgrade onboard components by eliminating the use of proprietary hardware and reliance on a single equipment vendor. This is a trend that is taking place in other industries and is emerging in the transit industry. There is a strong potential for cost savings if the onboard components of the recommended onboard architecture are replaced and integrated in conjunction with the ATMS II implementation.

The recommended bus and rail on-board architectures include common elements such as the mobile data terminal (MDT), mobile gateway router, GPS receiver, WiFi radio, automatic passenger counters, onboard video system, and onboard passenger information system that will result in cost savings due to economies of scale. It is recommended that the MDT for the bus, also be designed to serve as the control head for the farebox. The upgrade or replacement of other onboard rail components that interface to track wayside and rail control systems would not be a part of the ATMS project. Some of the recommended onboard components such as the MGR, APCs, and Wifi radio may be implemented by other Metro projects in advance of the ATMS II project

To most effectively implement the emerging onboard architecture and realize the cost savings, a detailed definition of the on-board architecture should be included in the ATMS II requirements definition work and implemented as part of the ATMS II project.

SUPPORTING SYSTEMS

Supporting systems are those elements of the Strategic Plan that further support the improvement of operational efficiencies and overall cost reduction through the implementation of common platforms and single-sources of information along with improved ease of use for Metro staff interacting with the systems. Supporting systems have been grouped by major technology area and include: traveler information, SCADA, video, and yard management. Some of the recommended projects in these categories build upon the improvements achieved with the foundational elements, such as leveraging the improved data sources found in the ATMS II implementation for traveler information or the ability to support real-time on-board video streaming through the improved data throughput achieved in the data communications projects.

Traveler Information

The Task 1 Needs Assessment identified clear needs related to improved traveler information, including improving the quality of real-time location and prediction information for bus and rail, incorporating service adjustments/alerts into traveler information feeds, and consolidating the dissemination of traveler information on the electronic information signs and PA systems.

The Strategic Plan recommends a set of projects categorized into the three overarching initiatives to help Metro meet these needs and greatly improve customer experience: 1) rail vehicle locations and arrival predictions, 2) multi-modal systems, including for service alerts, and 3) customer-facing systems. Improvements to vehicle locations and arrival predictions for the bus will be achieved through the implementation of the cellular data network and ATMS II.

Rail Vehicle Locations and Arrival Predictions

The need to improve rail vehicle location information and arrival predictions was identified as critical to improve both rail operations and the customer experience. These projects are necessary in order for Metro to operate a more robust multi-modal alerts system, expanding on the agency's existing real-time passenger information platform to provide accurate and timely rail vehicle location data and arrival predictions. The following recommended, sequenced projects offer best practice solutions with a risk-averse approach to future proofing.

RAIL VEHICLE LOCATION AND ARRIVAL PREDICTION RECOMMENDED PROJECTS

AVL BEACON

T.4 **GPS + Track Wayside Circuits and Beacons for Rail Vehicle Locations**	This project deploys GPS receivers on rail vehicles, beacons at platforms/stations and along the track, as needed, to support improved rail vehicle location and arrival predictions. This approach minimizes cost by leveraging existing infrastructure and use of cost-effective hardware to fill gaps. While the current systems largely meet operational needs, this additional level of granularity is necessary to provide more accurate and timely rail arrival predictions to customer information platforms. GPS data and beacons will augment the track wayside circuit data to improve rail vehicle location reporting. While the costs of the GPS devices are part of project T.4, the cost for T.4 may ultimately be reduced if the GPS devices are installed on the rail vehicles as part of the ATMS II project (A.5). It is recommended that the T.4 project be in progress or completed when the T.5 project begins.
T.5 **Rail-specific Prediction Engine**	This project develops a stand-alone arrival prediction engine for rail services to handle the specific rules and characteristics of rail vehicle travel and would improve Metro's rail prediction capability beyond what is currently available through NextBus. A rail-specific prediction engine would likely include factoring operating rules, such as maintaining a safe separation between trains; short-turns, diversions, bus bridges, and other real-time changes in service; and terminal operations in the prediction calculations. This project would utilize the additional rail vehicle location data provided by Project T.4 to improve the accuracy of the real-time rail vehicle predictions. It is recommended that the projects T.5 and T.3 are in progress or completed when the T.6 project begins.

Multi-modal Systems and Service Alerts

Metro stakeholders identified the need for a unified alerts system for bus and rail that more reliably shares system information to customers during service changes and disruptions, e.g. detours, bus bridges, etc. In addition, the transit information Metro provides to the public and other traveler information systems needs to be in standardized formats. While Metro provides schedule data through GTFS and arrival information through the NextBus API, a need was identified to provide data through the GTFS-realtime standard that leverages the existing GTFS schedule data by providing incremental updates where transit predictions are available. The consistency between the GTFS and GTFS-realtime datasets increases the utility and accuracy of websites and apps using this data, directly improving customer information.

The following recommended, sequenced projects, build on work completed to improve rail vehicle location and arrival prediction, and directly address these needs and ultimately meet the core goal of providing better quality information to customers and thereby increasing their trust (and use) of Metro services.

ALERT SYSTEM AND REAL-TIME INFORMATION AGGREGATION RECOMMENDED PROJECTS

INFO DISPLAY

T.3 **Multi-modal Alert System**	This project implements a new alert system to enter, manage, and disseminate alerts with a focus on streamlining the alert creation process and dissemination via multiple channels. This system will provide a platform through which alerts are entered into the real-time passenger information platform and should be developed prior to the Enhanced Multi Modal Real-Time Aggregation System (T.6).
T.6 **Enhanced Multi-modal Real-time Aggregation System + Single GTFS-realtime Feed**	This project builds upon the existing agency open data and API systems (i.e., developer.metro.net) to aggregate information from ATMS II, SCADA, Multi-modal Alerts System, and, possibly, from bus predictions from NextBus to provide a single-source of traveler information including vehicle locations, arrival predictions, and alerts. The project also includes the implementation of a new, single, GTFS-realtime feed that will provide improved accuracy on customer-facing portals like the Metro website and mobile app.

Customer-facing Systems

Metro stakeholders identified the need to improve the customer experience by making it easier for them to access traveler information. This will involve unifying the web pages available into an easier to navigate Metro traveler information website and mobile app. Web pages and apps that are able to leverage functionality from the customer's smart phones and mobile devices, such as GPS locations, improve the customer experience. Metro stakeholders have also expressed a need to consolidate the systems used to provide information to bus and rail passengers at stations and stops.

The following recommended projects also are envisioned to build upon the improvements of the other recommended Traveler Information projects.

CUSTOMER-FACING SYSTEMS RECOMMENDED PROJECTS	TRAVELER INFO
T.7 **Web pages with RTPI**	This project redesigns the Metro bus and rail arrivals web pages in order to provide real-time information including schedule, real-time predictions, real-time vehicle locations, and service alert information. The redesigned pages will allow users to access real-time information for their specific route, direction, trip, stop, or any combination thereof. These web pages could be integrated with either the NextBus API or the Bus and Rail Traveler Information System (TIS) API.
T.8 **NTCIP-compliant Station Signs with Common Sign Control**	This project replaces existing non-compliant signs with NTCIP-compliant signs at bus stops, rail stations, and transit centers and implements a common sign control system. This project reduces the number of systems required to maintain and operate, translating into direct operating cost reductions. The project also helps eliminate incorrect or inconsistent information being provided across the customer information platforms. The standardized signs should pull data from the Enhanced Aggregation System (T6).
T.9 **Rail Public Address System Upgrades**	This project upgrades the public address (PA) systems to provide one consistent system across all rail stations either through the implementation of new PA equipment or by upgrading existing PA systems at rail stations to be compatible with the unified system. The unified system will increase the reliability of the PA system and remove the complexities of managing multiple systems. The increases in capital costs to implement the new system would be offset by decreased operations and maintenance costs. A unified PA system will improve the transit experience of customers by providing a consistent experience across the system. Projects ATMS II Rail implementation (A.5) and the Enhanced Aggregation System (T.6) should be underway first, as the PA system will pull data from both newly implemented systems. There may be some cost reductions if this project is rolled into the rail elements under A.5.

SCADA

Metro stakeholders identified a significant need to make SCADA data available to other maintenance and security staff, in addition to the rail operations center (ROC) controllers. Although controllers at the ROC are primarily responsible for train movements, the nature of the current SCADA architecture also requires them to supervise and manage wayside systems and manage alarms, which are distractions from the higher priority of ensuring safe train movements. Maintenance staff, who are primarily responsible for the wayside systems, have limited direct access to SCADA information.

The following recommended projects provide maintenance staff with different access to SCADA information and assist with the management of alarms.

SCADA SYSTEM RECOMMENDED PROJECTS

SCADA

S.4 **SCADA HMI for Maintenance**	This project adds a SCADA interface for use by maintenance and security staff. The new SCADA interface would be constructed as an extension of the existing ARINC system with new workstations and new graphics that are optimized for maintenance functions but limit control capability to prevent accidental interference with the ROC controllers. The new graphics would include alarms for maintenance and security staff. The primary benefit is freeing the ROC controller from being an information conduit for maintenance and security staff and improving the efficiency and effectiveness of ROC controllers who can focus on train movements. Maintenance staff will benefit with an interface that is designed to specifically meet their needs and thus improve their efficiency and effectiveness. Security CCTV staff will also benefit with improved alarm displays for security-related points in the SCADA system.
S.5 **SCADA Message Gateway**	This project implements a message gateway with an interface to SCADA to automatically send emails, texts, or phone messages as triggered by alarms or events in SCADA. Implementation of this gateway can be accomplished with off-the-shelf alarm notification products that can be integrated with the SCADA HMI ARINC or utilize the ARINC SCADA platform to provide this functionality. The benefit of the message gateway is the reduction of the ROC controller workload. Controllers would still be able to maintain awareness of equipment readiness but would no longer need to contact maintenance responders.

Video

Metro stakeholders, especially security and operations staff, have expressed a need for the ability to view video from vehicles in emergency and other situations. The need for real-time access to onboard video will provide improved security for Metro operators and enable staff to better assess the onboard situation. Also, the onboard video will help Metro controllers determine when there is a false alarm and avoid having to dispatch law enforcement personnel to the vehicle.

VIDEO SYSTEM RECOMMENDED PROJECTS

LIVE VIDEO

V.3 + V.4 **Video Streaming for Bus and Rail**	This project implements the capability to stream onboard video from bus and rail vehicles to the BOC and ROC. It is recommended that the streaming only be done during emergency situations. This project assumes each vehicle already has a cellular data connection as a result of the implementation of the Bus Data (C.2) and Rail Data (C.5) projects. The video will be temporarily cached (but not stored) in the cloud, from where it is streamed to viewers during an incident. The key benefits of the streaming video are the improved security of the operator and passengers, and reduction of the need for the Sheriff's involvement when there is a false alarm.
V.5 **Video Tagging and Streaming**	ATMS II will include an interface to the onboard video system to enable video tagging during critical situations and will include the capability to activate video streaming from the vehicles during these situations.

Yard Management

Metro stakeholders have expressed key needs for an IT system to provide yard tracking and management functions for the bus and rail yards. The recommend project helps achieve the benefits from an IT system that will reduce the amount of manual labor currently performed by yard staff.

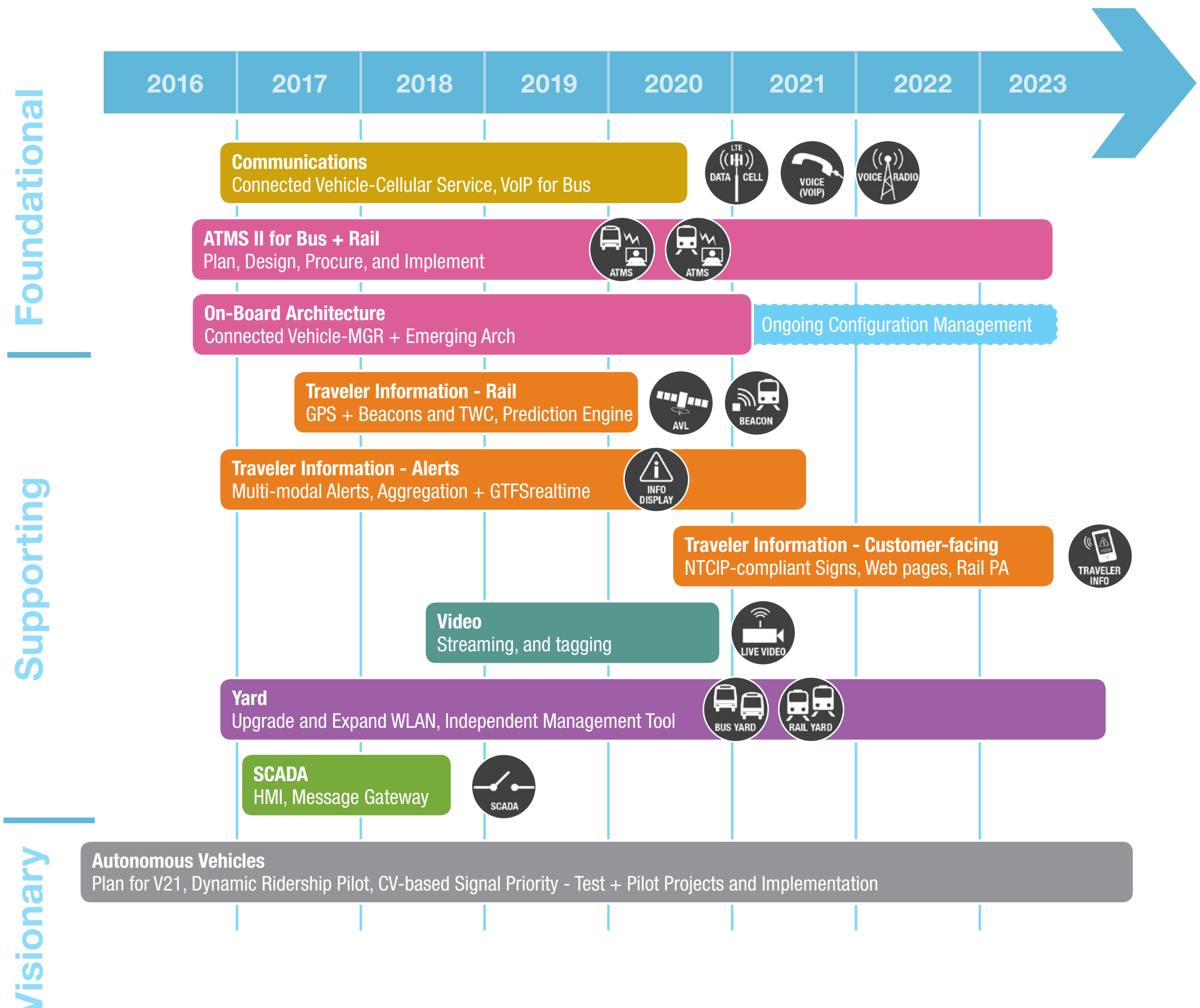
YARD MANAGEMENT SYSTEM RECOMMENDED PROJECTS

BUS YARD RAIL YARD

Y.4 + Y.5 **Prepare for and Implement Independent Bus + Rail Yard Management System Integration with ATMS II**	This project implements an IT system to provide comprehensive yard management functionality for the Metro bus and rail yards, and interfaces to other IT systems such as M3 via the TDB. The system uses devices such as RFIDs to accurately report the parking location of vehicles in spaces or tracks. Interfaces to M3 and HASTUS will support automated vehicle and operator assignments prior to and during the operating day. Implementation of a Yard Management system that is independent of ATMS II will enable Metro to consider a broader range of custom options that are more commonly seen for intermodal yard management. This solution will result in a reduction in the amount of manual labor performed by maintenance and operations staff and improve the efficiency of vehicle assignments and bus and rail roll outs.

STRATEGIC PLAN TIMELINE

Timelines for the recommended foundational and supporting elements of the Strategic Plan projects are shown in the figure below. Projects relating to Autonomous Vehicles being planned by Metro will be important when the Strategic Plan is updated in five years and are shown in the timeline for reference.



PROGRAM COSTS OVERVIEW

The following are rough order of magnitude (ROM) costs that have been developed for the recommended projects. Some of the cost estimates are based on costs provided by vendors and others are based on projected support required to procure, implement, and maintain the systems.

PROJECT	CAPITAL COSTS ($)	10 YEAR O&M ($)
Bus Data, Cellular	$2,516,000	$5,371,000
Bus Voice, VoIP	$5,072,000	$10,079,000
Rail Data, Cellular	$514,000	$1,212,000
ATMS II Bus	$68,267,000	$29,320,000
On Board Architecture, Bus	$2,436,000	$1,208,000
ATMS II Rail	$24,119,000	$14,800,000
On Board Architecture, Rail	$1,189,000	$874,000
Rail GPS, Track Circuits, and Beacons for Rail Locations	$2,772,000	$940,000
Rail-specific Prediction Engine	$562,000	$536,000
Rail PA System Upgrade	$1,985,000	$2,008,000
Multi-modal Alert System	$636,000	$1,027,000
Enhanced Multi-modal Real-time Aggregation System + GTFS-realtime	$1,871,000	$1,191,000
Web-pages with Real-time Passenger Info	$381,000	$433,000
NTCIP-compliant Station Signs with Common Sign Control	$6,815,000	$4,394,000
SCADA HMI for Maintenance	$683,000	$105,000
SCADA Message Gateway	$397,000	$12,000
Video Streaming for Bus and Rail	$6,120,000	$2,958,000
Yard Management System	$11,622,000	$5,699,000
TOTAL	$137,957,000	$82,167,000

There are some opportunities for cost reduction if certain projects are implemented concurrently due to a reduction in integration costs and duplicated hardware and project management costs. For example, if the implementation of data communications for bus and rail, VoIP, ATMS II Bus and Rail, and GPS tracking for Rail were implemented as a single project, the overall costs would be reduced by $8.1M. Other cost reductions can be realized if the software development costs for the Arrival Prediction, Improved Service Alerting, and Traveler Information Aggregation projects were implemented in conjunction with the ATMS II project.

RECOMMENDATIONS SUMMARY

In addition to the initiation of planning and securing the necessary approvals for the implementation of the Strategic Plan projects; the implementation of the Connected Fleet/Facilities project ensures the entire bus and rail fleets will be equipped with mobile gateway routers and have cellular data connectivity. Also, the new ESOC building should be considered as a site for the ATMS II central system for both bus and rail operations.

This Strategic Plan should be a living document and updated periodically—every five years or when Metro priorities and funding changes and to reflect new technology trends. IT systems should be updated/upgraded every five years; and hosted and Software as a Service solutions should be considered at that time.

Table of Contents

Table of Contents (continued)

List of Figures

List of Tables

Table of Contents (continued)

1 Overview

This section provides an overview of the Bus and Rail Fleet Systems Strategic Plan project by discussing project purpose, identified needs and subsequent alternatives analysis, the existing Metro technology environment, and provides a high-level overview of Plan recommendations.

The breadth and depth of bus and rail fleet systems currently utilized and planned for at Metro are extensive and represent unique challenges in terms of developing a meaningful Strategic Plan that covers the knowledge and issues required without becoming burdensome in its use for longer-term planning purposes. The Strategic Plan presented here aims to outline a clear and actionable set of projects that together provide Metro with a forward-looking transit technology program. The primary goals of the Plan, revisited and supported throughout, focus on improving Metro's operational efficiency and reliability, as well as providing systems to improve the customer experience and satisfaction.

1.1 Purpose and Scope of the Strategic Plan and Concept of Operations

This Bus and Rail Fleet System Strategic Plan (Plan) provides the Los Angeles County Metropolitan Transportation Authority (Metro) with a clear and actionable set of recommended projects to best support the needs of the agency's fleet technology program, as well as strengthen its customer-facing tools and information. Overall, the Strategic Plan represents a logical and phased blueprint for fleet and communications systems replacements and upgrades to significantly enhance functional and operational capabilities while providing Metro with forward-looking technology solutions. The recommended projects have been mapped to timelines, with dependencies between projects identified along with overall Rough Order Magnitude (ROM) costs broken down by primary program areas. Concept of operation scenarios illustrate how the recommended projects will improve Metro's fleet operations and improve the customer experience.

1.2 How to Use This Document

This document is intended for use by Metro department heads and lead staff as they work through internal budgeting efforts to enable them to better identify the best sequencing for and potential bundling of recommended projects. This also provides the supporting information necessary to justify the projects.

The Plan has been organized into the following major sections:

Executive Summary – The summary provides an executive-level overview of key Strategic Plan technology program goals, overall timeline for the various program elements, recommended projects, related project dependencies, and ROM costs.

Section 1: Overview – This section provides an introduction to the Strategic Plan, describing the project background, Metro's major needs, alternatives assessment methodology, and a high level description of the Strategic Plan recommendations.

Section 2: Foundational Elements – This section describes the "foundational elements" for Metro to achieve its strategic goals and objectives and meet the needs identified. Foundational elements include communications system improvements, on-board architecture improvements, and the ATMS II for bus and rail implementation that will serve as a backbone for all other bus and rail fleet systems; providing a

reliable source for bus and rail fleet data, as well as improving operational efficiency through the use of new and improved tools available today.

Section 3: Supporting Systems – This section describes supporting systems—elements of the Strategic Plan that further support improvement of operational efficiencies and overall cost reduction through the implementation of common platforms and single-sources of information along with improved ease of use for Metro staff interacting with the systems. Supporting systems have been grouped by major technology area and include traveler information, SCADA, video, and yard management.

Section 4: Strategic Plan Timeline and Relationships between Fleet Systems – This section provides a timeline for the complete technology program described in this Strategic Plan. The timeline identifies key dependencies between current, planned, and recommended projects. This section also provides diagrams that identify new or updated system interfaces that will result from the implementation of the recommended projects.

Section 5: Rough Order of Magnitude Program Costs – This section provides rough order of magnitude (ROM) costs with detailed costs for each recommended project, including ten years of operations and maintenance support.

Section 6: Technology Trends and Impacts – This section provides a discussion of emerging and future trends and their impact on future projects. The technology trends will allow Metro to more easily and cost effectively implement future technologies.

Appendix A: Concept of Operations Scenarios – This section provides scenarios that illustrate how the recommended systems will improve Metro's operations and the customer's travel experience.

Appendix B: Technology Program Project Descriptions – This section provides descriptions for current/planned fleet system projects undertaken by LA Metro.

Appendix C: Key Terms – This section provides a definition of key terms used throughout this document, including acronyms and other Strategic Plan-specific definitions.

1.3 Background

In order to define a set of achievable projects supporting Metro's overall bus and rail fleet systems program, this project began with a series of needs assessment workshops and interviews to identify current bus and rail needs, assess existing fleet and communications systems, and identify on-going and planned program systems development efforts. The findings were then summarized in an interactive workshop followed by the *Technical Memorandum 1: Needs Assessment* and first iteration of *Technical Memorandum 2: Initial Communications Assessment*. Following completion of the needs assessment, an alternatives assessment was completed, evaluating a series of fleet and communications alternatives across the broad range of identified needs. Evaluation criteria used a common approach and considered the technical ability of each alternative to meet identified needs, benefits, strengths, weaknesses, opportunities, threats, capital and O&M costs, implementation timelines, associated risks, benchmarking by other transit agencies, and whether the alternative would require significant updating to work as technology advances (i.e., "future proofing"). The highest scoring alternatives were reviewed with Metro in an interactive workshop and then carried forward as the recommended projects for this Plan.

1.3.1 Major Needs Areas

At each stage of the assessment and evaluation, the potential projects for Metro's bus and rail fleet systems program were traced back to the critical needs identified during the initial workshops and refined throughout the project as new information came to light. These needs directly address improving operational efficiencies, customer experience, and safety and security and are detailed in the following major categories:

- Better communication reliability and data throughput. This includes voice, data, and yard communications systems. While currently operating adequately, the existing bus voice radio system, including radio dispatch consoles, is aging with many components reaching the end of their useful life and needs to be replaced to ensure future reliability. There are also significant challenges with the current capacities, functionality, and coverage or lack thereof of Metro's mobile data communications for both the bus and rail fleets. Data communication is the foundation of all modern fleet management systems and critical to providing more accurate and timely transit information to customers. As an exacerbating factor to the issues with mobile data communication, there are substantial constraints on the wireless data communications coverage and capacities in the bus and rail yards. Despite the relatively recent Aruba implementation for the bus yards, there are already capacity concerns that will only become more significant as data needs expand. Metro is undertaking some pilot efforts to test options for providing yard Wi-Fi coverage through unique partnerships, as well as testing new yard handheld tablet applications, and this Plan encourages further development along this path.
- Enhanced and streamlined computer aided dispatching and incident management. While operating adequately in some respects, the current ATMS is an earlier generation CAD/AVL system that lacks state-of-the-art mapping, service adjustment/restoration functions, streamlined performance monitoring tools, and many other features that would improve operations and provide better information to customers. Metro bus controllers do an excellent job of using ATMS to capture incidents/events information, but do not have adequate tools to manage service impacts and interruptions. In short, ATMS is serving a valuable role to document what occurs on a daily basis, but it is lacking in tools to help proactively monitor and respond to operational issues. For rail controllers, SCADA solutions offer good train control and safety monitoring features. However, there is no support for text messaging between controllers and operations. This was viewed by ROC personnel as a major tool needed to provide timely and accurate information to rail operators for non-critical items. In addition, incident logging and reporting for rail controllers is currently done through M3, which has limited functionality and is not operationally integrated with SCADA.
- Modern, updated, and flexible on-board architecture. While state-of-the-art at the time it was implemented, Metro's current on-board systems architecture has become dated and consists of a wide range of devices, interfaces, and functionality. It is essential an updated on-board architecture be established for the bus and rail fleets that recognizes the unique elements of each and provides a more flexible foundation for future technology integration and improvements.
- Robust, integrated traveler information systems. A core mission of any transit agency is providing transit customers with reliable and timely information on services and service interruptions. As mobile data and information technologies have evolved, the capabilities and expectations of transit customers have dramatically changed, and their demands for timely and accurate data have increased exponentially. While Metro does a good job of

capturing data for operations purposes, as well as providing improved information dissemination options, there are significant limitations of the current transit traveler information systems.

- Real-time on-board video, video data storage, and distribution improvements. Video from a variety of fixed platforms/facilities, buses, and rail vehicles is a crucial security, safety, and risk management tool. It is also presents a primary challenge from a systems, communications, and operations process standpoint. While Metro is undertaking the digital incident management system (DIMS) project to better integrate and manage requests for video and its distribution, there are significant challenges in terms of the variety, age, and capabilities of the range of fixed and mobile video platforms. Rail and bus operations as well as security groups, have all requested the ability for live look-in for vehicles in emergency situations. Current security threats will continue to push for greater video capabilities and access. Bus controllers noted that a live look-in feature would allow for some much needed process changes in responding to false emergency alarms on buses, as a very high percentage of reported alarms end up being false and require a considerable amount of law enforcement resources to resolve them.

Along with the above major needs areas, the following additional needs were identified and addressed in this Plan:

- Improved SCADA Interfaces. Controllers at the ROC who use the SCADA HMI are primarily responsible for train movements, but the nature of the SCADA architecture also requires them to supervise and manage wayside systems unrelated to train movements. The additional responsibility of the wayside systems is a distraction from the higher priority of ensuring safe train movements. SCADA provides monitoring, alarms, and control of equipment for the following systems: traction power, train control, electrical, mechanical, tunnel ventilation, communications systems, fire detection, security, and other miscellaneous systems. The alerts and information for rail operations and maintenance that SCADA generates are not easily accessed outside of the SCADA systems. Maintenance and security staff who are primarily responsible for the wayside systems have limited direct access to SCADA information
- Improved Yard Management tools. Vehicle management, status tracking, and maintenance support functions performed by Metro staff at the maintenance facilities are currently done manually. Yard management tools could assist with tracking status of vehicles and vehicle maintenance/yard spotter functionality, while providing automatic integration of its data into M3.

1.3.2 Alternatives Assessment Methodology and Outcomes

The Alternatives Assessment Technical Memorandum was the third major element of the Metro Fleet and Communications Systems Strategic Plan, with the first two being the Needs Assessment and Communications Assessment. As part of technical efforts for this project, a series of fleet and communications systems alternatives were assessed across the broad range of Metro-defined areas of need. For organization purposes, the major sets of systems alternatives reviewed were again divided into the major needs areas, and each alternative was analyzed to assess the technical ability of the alternative to meet identified needs, benefits, strengths, weaknesses, opportunities, threats, capital and O&M costs, implementation timelines, risks of implementing the alternative, benchmarking where the alternative may have been implemented by other transit agencies, and whether the alternative will need significant

updating to work as technology advances. Each of the alternatives were scored and compared within the specific area being considered in order to provide inputs and suggested implementation paths for the final Fleet and Communications System Strategic Plan. The scoring and recommendations outlined in the alternatives assessment technical memorandum served as materials for discussion and review leading into the final stages of the project providing a short-hand for the completed technical analysis. Many of the alternatives overlapped or were interrelated. The alternatives assessment effort did not attempt to correlate all possible implementation paths; however, as feedback was received on the recommended alternatives, the implementation plan for interrelated alternatives has been addressed in the Strategic Plan itself. The recommended technology program described in this Strategic Plan was built based on the high-scoring alternatives from this phase of the project.

1.4 Existing and Planned Systems

Metro currently has several bus and rail fleet systems projects underway or planned that will impact the projects recommended in this Plan. In some cases, the current or planned projects are being leveraged for further technical advances, cost savings, condensed implementation timelines, or some combination of the three as described later in this memorandum. It is important for agencies to take this kind of programmatic view as it offers them the best options and opportunities to meet sometimes conflicting goals and objectives, such as whether the need for a reliable communications system supersedes the need to manage cost by implementing communications upgrades and replacements as part of the recommended ATMS II project. Further, any dependencies identified between planned and recommended projects have been included in this Strategic Plan as it will be critical for Metro to have a clear view of the assumptions upon which some recommendations were based on.

1.5 Strategic Plan Recommendations

Several recommended technology solutions supporting improvements to Metro's operating and business environments and, more importantly, customer experience have been identified over the course of this project. These solutions make up an overall technology program Metro will be able to implement over the next several years in a coordinated, phased approach to replace and update aging ITS systems and improve customer-facing systems. The Strategic Plan also takes into consideration both current and planned Metro projects.

The recommended projects presented in this Plan have been grouped into two main categories: foundational and supporting projects. Foundational projects improve the backbone of Metro's fleet technology systems that will have the most significant impact on the improvement of operations, address the most needs, and have the greatest impact on other solutions. These include:

- Communications system improvements necessary to successfully implement several of the recommended projects, achieve the improvements envisioned, and maintain the systems in a state of good repair.
- ATMS II Bus and Rail implementation, which will serve as a backbone for all other bus and rail fleet systems, provide a reliable source of bus and rail fleet data, and improve operational efficiency through the use of new and improved tools that are currently available in the technology market.
- On-board architecture improvements necessary to best leverage the communications system and ATMS II improvements and position the agency to be prepared for implementation of future, emerging technologies

Supporting projects build upon these foundational elements to offer the agency and its customers a fully realized Strategic Plan. It is anticipated that timelines in the Strategic Plan may shift based on funding availability and changing priorities, but the relationships between the projects, the overall cost estimates, and the project scope elements will remain essentially the same. Supporting systems have been grouped by major technology area and include: traveler information, SCADA, video, and yard management. Some of the recommended projects in these categories build upon the improvements achieved with the foundational elements, such as leveraging the improved data sources found in the ATMS II implementation for traveler information or the ability to support real-time on-board video streaming through the improved data throughput achieved in the data communications projects.

In addition to the initiation of planning and securing the necessary approvals for the implementation of the Strategic Plan projects, implementation of the Connected Fleet Vehicles & Facilities project is important so the entire bus and rail fleets will be equipped with mobile gateway routers and have cellular data connectivity. Also, the new ESOC building should be considered as a site for the ATMS II central system for both bus and rail operations.

This Strategic Plan should be a living document and updated periodically—every five years or when Metro priorities and funding changes or to reflect new technology trends. The update of this Strategic Plan should take into consideration other strategic plans developed by Metro and its regional partners.

2 Foundational Elements

This section describes elements of the Strategic Plan technology program that must be in place to not only support improved operations and customer experience today, but also to better prepare Metro for future technology solutions.

The following recommended projects are considered "foundational elements" for Metro to achieve its strategic goals and objectives and meet the needs identified. These foundational elements include communications system improvements, which are necessary to successfully implement several of the recommended projects and/or achieve the improvements envisioned; ATMS II for bus and rail that will serve as a backbone for all other bus and rail fleet systems providing a reliable source for bus and rail fleet data, as well as improving operational efficiency through the use of new and improved tools available in the market today; and on-board architecture improvements, which are necessary to best leverage the communications system and ATMS II improvements and position the agency to be prepared for implementation of future, emerging technologies.

2.1 Communications System Recommendations

Metro operates a large and expanding bus and rail system for the County. The Strategic Plan includes strategies for how the communications systems need to support Metro's IT systems that assist in the operation of the bus and rail fleets. During the initial needs assessment phase, the existing conditions, technology trends, and telecommunications needs were documented as inputs to the strategy. Some existing systems, such as the recently upgraded voice radio system for rail, were identified as being sufficient, while others were identified as requiring significant investment, such as the bus data communications system, due to insufficient capacity and age of the existing equipment. For systems that required significant upgrades or replacement, alternatives were identified and assessed utilizing the methodology described in Section 1.3.2. The highest rated alternatives are the recommended solutions discussed below in this document. *Technical Memorandum 2: Communications Plan* also provides more details regarding recommended implementation approaches.

2.1.1 Bus Communications System Recommendations

This section reviews the voice and data communications solutions recommended for Metro under the technology program described in this Strategic Plan.

Voice Communications for Bus

As discussed in the Needs Assessment phase (Task 2: Initial Communications Assessment), the bus voice radio system is nearing the end of its lifecycle and both on-board and central system equipment will need to be replaced within the near term of the Strategic Plan timeline. The following section discusses the recommended solution for voice communications for the bus fleet: a Voice over Internet Protocol (VoIP) voice communications system. Since VoIP is a relatively new technology compared to land mobile radio (LMR) systems, it is recommended Metro retain the current ATMS voice radio system as a fall-back voice communication option for a period of time to reduce risk. The voice radio system would be treated as a standalone solution and would only be utilized in cases where the VoIP system was not functional for some reason. The current ATMS voice radio is only recommended to be a temporary fall back solution until the agency is comfortable with the VoIP system, at which time the existing LMR system would be retired.

Establish VoIP Communications for Bus Fleet
Project: C.3

For this project, Metro implements a new VoIP system. This system would be implemented as part of the larger ATMS replacement effort, as the Computer Aided Dispatch vendor selected through an ATMS II procurement would need to provide the integration and CAD control for the VoIP system. The VoIP system would utilize a high-speed, broadband data communications system.

Benefits

- A VoIP system will have better coverage and greater capacity than the ATMS voice radio system.
- The cellular provider would maintain the network.
- VoIP could be implemented quickly, much faster than the implementation of an LMR system and the capital costs would be significantly lower.
- By implementing VoIP, Metro would avoid the high costs to repair breakdowns of the current aging system and to find spare equipment.

Technical Analysis Summary

VoIP solutions are a relatively recent option for the transit industry that have emerged in the last few years. However, as discussed in *ATMS 2: Initial Communications Assessment*, this is rapidly becoming the industry trend. This solution is based on the underlying assumption that a high speed, high bandwidth data network has been or will be implemented by Metro. This assumption is addressed in the subsequent section of this document on bus data communications.

While the migration to VoIP is an emerging trend in transit for service mobile voice communications needs, it is not without risks. One of the significant benefits of having the voice network and the data communications network on two separate systems (as is the current architecture for bus communications) is the additional level of redundancy that comes with that. If there is a temporary network outage on the voice network for example, the data network may still be operating, allowing the continued tracking of vehicles and the ability to at least communicate with a bus via canned and text messages. If VoIP is implemented using the network used for data communications network, this redundancy would be lost. There are also concerns about network congestion affecting both data and voice communications, resulting in lost voice communications. This concern has been particularly identified with the use of cellular data networks. As well, because this trend is relatively new in the industry (the consultant team is only aware of four operational systems in the US), there is no guidance or recommendations on this technology from industry organizations such as the American Public Transit Association (APTA). However, it should be noted that VoIP is being used by various international transit agency fleets, including some European and Asian transit agencies which operate very large fleets that are similar to Metro in size.

VoIP is a relatively recent technology that has matured from “emerging” into “mainstream” in the last few years. There are risks due to the lack of maturity of the technology and the lack of redundancy when both voice and data communications rely on a single network. There is additional risk that system availability may be limited during a catastrophe. These risks can be mitigated by implementing on-board routers that are capable of utilizing multiple communications paths, including cellular data (from multiple carriers),

radio system, Wi-Fi, and other networks. This would enable Metro to utilize the current ATMS voice radio system or other systems such as LA-RICS as a backup to VoIP.

Benchmarking

In the US, there are only four known VoIP implemented systems that have been in operation for some time. Many other agencies, including AC Transit and Foothill Transit are currently in the implementation phase of their VoIP systems. The four fully accepted US systems include: CENTRO in Syracuse, NY; SMART in Detroit, MI; NICE in Long Island, NY; WRTA in Worchester, MA.

Some European and Asian examples of mature VoIP systems include: SMRT in Singapore, Ingolstadt GER, Luxembourg, Oldenburg GER, BKV Zrt, Budapest – Hungary, Mainzer Verkehrsgesellschaft mbH (MVG), Mainz – Germany, Kraftverkehr Wupper-Sieg AG (KWS), Leverkusen –Germany, Transportation Bureau of the City of Nagoya, Japan, and CTB/NWFB in Hong Kong.

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 5.1M	$ 10.1M

Additional cost break down information may be found in the ROM Section 5.

Assumptions

- Cellular data or another broadband data solution will be implemented in conjunction with or in advance of the implementation of the VoIP solution.

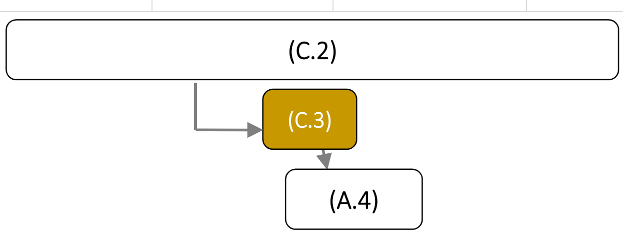
Implementation Considerations

This project assumes that a high-speed broadband data communications system (such as 4G LTE or LA-RICS LTE) will either be implemented in advance or in conjunction with the migration of bus communications to VoIP. Metro could continue to utilize the existing agency owned voice radio system as a back-up solution for as long as the equipment is operational or until Metro is completely comfortable with the stability and reliability of the VoIP solution. This work should be implemented as part of the ATMS replacement project, as the VoIP solution is largely a software based solution and one that will need to be heavily integrated with and controlled by ATMS II.

Implementation Schedule and Key Dependencies

The timeline below illustrates the implementation of the VoIP solution for bus voice communications, its dependency on the cellular data network for bus communications project, and the recommended timing with the ATMS II project implementation.

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*



(C.2) Connected Vehicle: Establish (Commercial) Cellular Data Service for Bus Fleet

(C.3) Establish VoIP Communications for Bus Fleet

(A.4) ATMS II Supplier Procurement for Bus & Rail

Data Communications for Bus

As discussed in the Needs Assessment phase (Task 2: Initial Communications Assessment), the bus data radio communications system is not meeting all of Metro's operations requirements (such as vehicle location polling rates). The current system does not have adequate capacity to support future data needs and is nearing the end of its lifecycle. Both on-board and central system equipment will need to be replaced within the early phase of the Strategic Plan timeline.

The alternatives assessment for bus data communications rated use of a commercial cellular data network highest with the LA-RICS network second. The cellular data option poses less risk to Metro, as the networks are already fully built out with full regional coverage and have the network capacity to support Metro operational needs. In addition, commercial cellular data plan costs have plummeted; competition keeps the cellular companies on a constant program of improving their network capacity and coverage; and 5G service is slated to be rolled out in 2020. However, the LA-RICS system offers much promise in terms of comparable data communications technology and may have similar coverage. The fact that the system will be owned, operated, and maintained by regional partner agencies may prove beneficial in terms of long-term costs and control of the network. Therefore, it is recommended that Metro consider proceeding with a more comprehensive analysis of both alternatives before making the significant investment in system replacement.

Connected Vehicle: Establish (Commercial) Cellular Data Service for Bus Fleet

Project: C.2

Metro, following completion of a drive test to compare coverage from the cellular data providers, will migrate bus data communications to the commercial cellular data network with the best coverage and performance. Metro would purchase all new cell cards/radios and would subscribe to service on the cell network by paying monthly charge per card/radio on the network. Metro would no longer own or maintain site data radio equipment and maintenance of the on-board cards would become a shared responsibility between Metro and the cell provider. If the data network is implemented before the ATMS II project, Metro would need to integrate the new cellular radio equipment with the current ATMS to maintain existing operational processes.

Benefits

- The cellular data network will have better coverage than a radio system.
- The cellular data plan chosen will enable the vehicle location update rate to be lowered to 30 seconds or less and would result in improved vehicle location reporting and improved accuracy of the passenger information systems.

- The cellular data plan will include sufficient capacity for the buses to transmit additional vehicle health information and for buses in an alarm state to transmit real-time video clips to improve the security of the operator and passengers.
- Maintenance costs are lower than a Metro owned system because the system would be maintained by the cellular provider.
- The cellular data network could be implemented quickly with lower capital costs than a Metro owned system.
- By implementing a new data system, Metro would avoid the high costs to repair a breakdown of the current aging system and to find spares.
- Implementation of the cellular data network enables a VoIP solution to be possible for voice communications.

Technical Analysis Summary

Utilization of a cellular data network for bus fleet data communications best meets Metro's data communication needs. The cellular data alternative scores well in virtually all of the evaluation categories including performance, and future proofing. The recent drops in cell data network pricing for transit agencies has made this data communication alternative attractive from not only a Capital but now an O&M standpoint. The fact that the networks are completely built out, means that the schedule for deployment is much shorter. Network capacity meets all of the agency needs and future upgrades lower agency risk.

Benchmarking

The majority of recent data communications systems have been implemented using commercial cellular data, including dozens of agencies across North America. Locally, Foothill Transit, Montebello Bus Lines, Culver CityBus, and Torrance Transit are employing a cellular data network for their SmartBus systems.

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 2.5M	$ 5.4M

Additional cost break down information may be found in the ROM Section 5.

Assumptions

- Metro continues to expand the pilot program to roll out on-board mobile gateway router technology for the full fleet and that this router would become the primary data communications manager for all functions including Wi-Fi, CAD/AVL, vehicle diagnostics, fare collection and video/security systems. The utilization of on-board routers, could be implemented as part of the project or in advance of it. While on-board routers are not mandatory to support the migration to cellular data, they are strongly recommended.
- All sites, network infrastructure and backhaul network(s) would be provided by the cellular data provider.

- Vendors provide a solution that is relatively easily integrated with either the existing ATMS or its replacement.
- All mobile units will be replaced by cell data cards in mobile access routers.

Implementation Considerations

Determination of timing of a replacement of ATMS is critical, and if it is going to proceed in the near term, it is strongly recommended that the data communications system be replaced at the same time or be completed before the ATMS II implementation. This alternative could proceed very quickly since the commercial cellular networks already exist.

Mobile Gateway Router (MGR)

A robust MGR may already be installed on the buses as part of the Connected Fleet Vehicles & Facilities project before the cellular data network implementation begins. If the MGR has not yet been implemented fleet-wide, and if an MGR requirement is added to the bus data communications system project, an additional $5M in capital costs must be included. This recommendation was also included in the voice system replacement and should only be accounted once.

The MGR is considered a critical component of the on-board system of the future for several reasons, and is addressed in much more detail in other sections of this Strategic Plan. Three of the key issues worth mentioning here relating to the MGR are as follows:

1. The MGR will allow the vehicle to make use of the best available data network for each bus. This may include utilizing an agency (or partner) built Wi-Fi network in the bus yard or in other sections of the network, connected vehicle technology when available, and then transferring over to a cellular for wide-area network coverage;
2. The MGR will support a more graceful transition to another wide area data solution in the future, without requiring significant impact on other systems. This “future proofing” of the data system, will allow Metro the flexibility to start with one data solution initially (e.g. commercial cellular in the near term), with the flexibility to switch to a different solution (e.g. LA-RICS or a subsequent migration into FirstNet), if their cost and performance become more preferable in the future; and
3. The MGR supports the routing of particular network traffic in different levels of prioritization depending on conditions. For example, Metro may choose to enable full motion remote video viewing, but only when vehicles are in Wi-Fi or other high-speed networks. Specific traffic, such as fare collection or VoIP traffic, could always take higher priority over all other traffic. This type of functionality allows Metro to optimize and prioritize mobile data communications to best meet operational needs.

Drive Testing of the Network

Because of the investment associated with the bus data network replacement project and because of the importance of a high-quality mobile data network to support the voice system recommendation of VoIP, it is strongly recommended that Metro perform extensive due diligence on both the cell carriers’ networks and also on the LA-RICS LTE network. This testing can be carried out simultaneously for all networks with a coordinated drive testing effort, and data collection can be augmented and expanded, by equipping some operating vehicles with data collection equipment for a more extended drive test.

Drive testing should be performed by experienced wireless communications experts, and should collect data to test all networks for the following:

- Coverage: categorized and mapped into different levels of received signal strength (RSS) throughout the service area;
- Throughput: network bandwidth measured in Mbps at individual points in the network. It should be noted that throughput can vary drastically in different parts of the day due to network congestion. This should be factored into the test methodology.
- Latency: speed (or delay) in which a signal is received from the time that it is sent;
- Jitter: the variation in the latency over time. This is particularly important for supporting VoIP;
- Packet loss: measured percentage of the failure of one or more data packets to reach their destination. Also important to support VoIP, as well as, other data applications.

Figure 1 and Figure 2 show some real-world results of recent drive testing performed for another transit agency. This testing can help select between commercial cellular carriers or between commercial cellular carriers and LA-RICS to help determine if multiple carriers or multiple networks are required to meet Metro's needs, and can help with the system design and its optimization in the future.

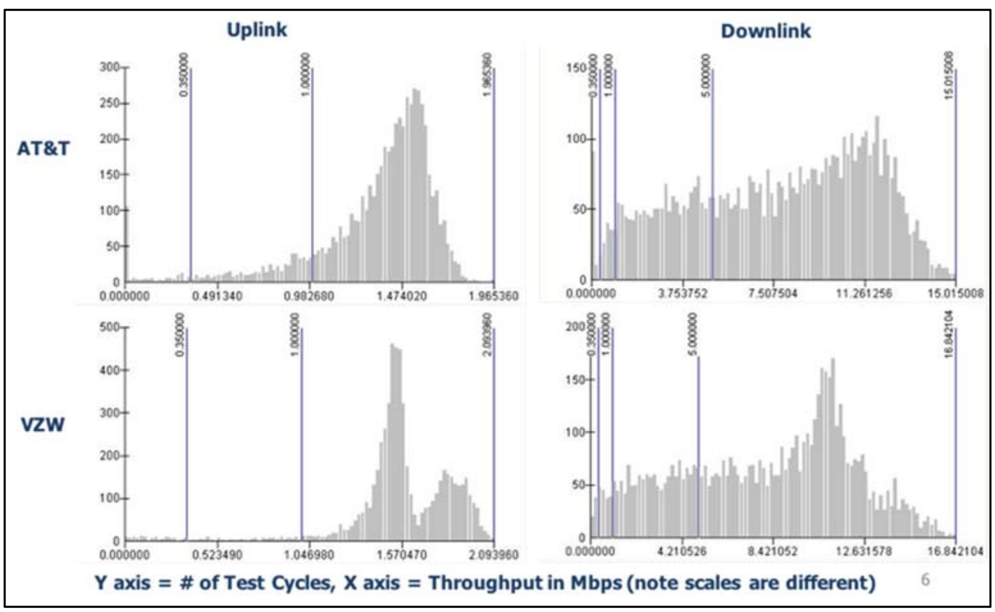


Figure 1: Example Throughput Probability Density Functions

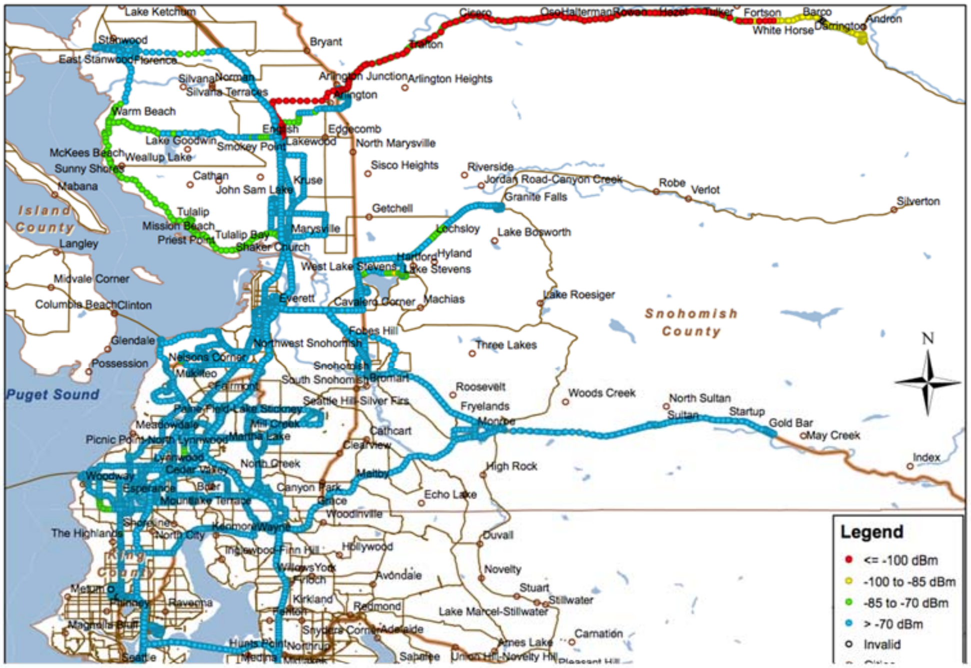


Figure 2: Reported RSS for One Carrier

Negotiate with both LA-RICS and Commercial Cell Carriers before Selection

Cell carrier pricing is now available through the Western States Contracting Alliance (WSCA) pricing agreements for various data plans including pooled data plans, which can be very advantageous for transit agencies with wide variation between individual vehicle data needs. It is particularly worth noting, that the cell companies consider this kind of data communications to fall under the machine-to-machine (M2M) data category. M2M communications have an even lower cost than other voice or data plans. Because of the highly competitive mobile data communications arena, even the WSCA pricing can often be negotiated even lower, especially by agencies with large fleets and extended buying power.

LA-RICS is currently not able to provide very detailed pricing information until an agency enters into a more formal stage of expressing interest. The true costs of “buying in” to the network along with more accurate monthly data plan pricing would be required to fully assess the capital and O&M costs of this alternative solution. Having the drive testing results along with more updated pricing from the commercial carriers would put Metro in a more advantageous position for these negotiations.

Backup Systems

If the drive tests show comparable coverage between the cell carrier’s networks and the LA-RICS network, and the costs are also comparable, Metro should consider utilizing LA-RICS as the primary data network for the bus fleet with a cell carrier’s data network as a backup. Since the cell data network would only be used as a backup, Metro could put the entire bus fleet in a low cost, low data usage pooled plan.

If the drive tests show that the LA-RICS network shows good promise but needs further development to provide adequate coverage, Metro could still utilize LA-RICS as a the primary data network for the bus fleet and utilize the cell data network as a backup until the LA-RICS network is fully built out.

Migration to 5G

As mentioned above, it is likely that the cell providers will be offering the opportunity to migrate to 5G within the next four to five years. 5G will bring significantly more bandwidth, but its pricing is uncertain. It is recommended that any cellular cards or chips that are procured be capable of supporting both 4G/ LTE and 5G. It is further recommended that Metro do specific negotiations around the 5G transition, to see if it is financially feasible at the time of procurement.

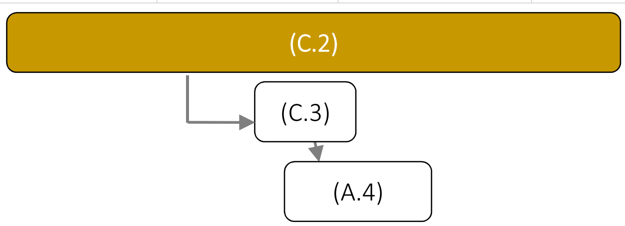
Connected Vehicle Technology

Metro is currently implementing a pilot test of Connected Vehicle technology on a couple of limited corridors with a grant proposal for the full Connected Fleet Vehicle & Facilities project. The data radios being deployed on this pilot are capable of transmitting in multiple bands, including Wi-Fi and Dedicated Short Range Communications (DSRC), which is a licensed spectrum dedicated only for transportation purposes. This ultra-high-speed and high bandwidth network may support Bus Signal Priority (BSP), transit safety applications still in development, and may support other agency data communications needs. While the Connected Vehicle technologies are very promising, they will not be fully deployed for a long period of time and are not, at this time, considered a wide area data communications alternative.

Implementation Schedule and Key Dependencies

The timeline below illustrates the implementation of the cellular data network for bus communications and how the timing of this project affects the implementation of the VoIP for bus voice communications solution and the ATMS II project.

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*



(C.2) Connected Vehicle: Establish (Commercial) Cellular Data Service for Bus Fleet

(C.3) Establish VoIP Communications for Bus Fleet

(A.4) ATMS II Supplier Procurement for Bus & Rail

2.1.2 Rail Communications System Recommendations

The following section describes the communications system recommendations for rail.

Voice Communications for Rail

As discussed in the Needs Assessment phase (Task 2: Initial Communications Assessment), the rail voice radio system is a relatively recent implementation. If the new Icom voice radio system is adequately maintained, it should support Metro's needs for the majority of the timeframe assessed in this Strategic Plan. Maintenance of the radio system includes ensuring there are no coverage gaps and there are sufficient licensed channels to support the voice traffic loads as Metro expands its rail service. While it is possible that Metro will need to begin an assessment of rail radio replacement options toward the end of

the Strategic Plan timeframe, there does not appear to be any compelling reason to consider migrating rail voice communications onto a single shared radio system with bus operations in the near future.

Data Communications for Rail

Metro stakeholders identified key needs for the establishment of a rail data communications system to enable data communications with operators and to wirelessly upload and download data to/from the rail vehicles. A data rail communication system will be necessary to support other projects in the Strategic Plan including ATMS II Rail and GPS tracking of the rail vehicles.

As with the bus data communications recommendations, the alternatives assessment for rail data communications rated use of a commercial cellular data network highest with the LA-RICS network second.

Connected Vehicle: Establish (Commercial) Cellular Data Service for Rail Fleet

Project: C.5

For this project, Metro implements a data communications system for rail in a similar manner as the implementation of the bus data communication system.

Metro would purchase all new cell cards/radios that are **rail certified** and would subscribe to service on the cell network by paying a monthly charge per card/radio on the network. Metro would need to integrate the new cellular radio equipment with ATMS II.

Benefits

- Enables real-time data messaging to operators and other CAD functions
- Enables real-time vehicle location updates, the update rate would be 30 seconds or less
- Enables real-time transmittal of vehicle health information
- Better coverage than a radio system.
- Enables the streaming of real-time video from the vehicle
- Maintenance costs are lower than a Metro owned system because the system would be maintained by either the cellular provider.
- The cellular data network could be implemented quickly with lower capital costs than a Metro owned system.

Technical Analysis Summary

As with the analysis performed for bus data communications, utilization of a cellular data network for rail fleet data communications best meets Metro's data communication needs. The cellular data alternative scored well in virtually all of the evaluation categories including performance and future proofing. The recent drops in cell data network pricing for transit agencies has made this data communication alternative attractive from not only a Capital but also an O&M standpoint. The fact that the networks are completely built out, means that the schedule for deployment is much shorter than for a radio system. The network capacity meets all of Metro's needs and future upgrades lower Metro's risk.

Benchmarking

Santa Clara Valley Transit Authority (VTA), RTD and WMATA have implemented a cellular data solution for its rail operations.

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 514K	$ 1.2M

Additional cost break down information may be found in the ROM Section 5.

Assumptions

- Rail certified mobile units will need to be procured and installed.
- Metro continues to expand the pilot program to roll out on-board mobile gateway router technology for the rail fleet and this router will become the primary data communications manager for all functions including Wi-Fi, CAD/AVL, vehicle diagnostics, and video/security systems. The utilization of on-board routers, could be implemented as part of the project or in advance of it. While on-board routers are not mandatory to support rail data communications, they are strongly recommended.
- All sites, network infrastructure and backhaul network(s) will be provided by a cellular data provider.
- Vendors can provide a solution that is relatively easily integrated with ATMS II.

Implementation Considerations

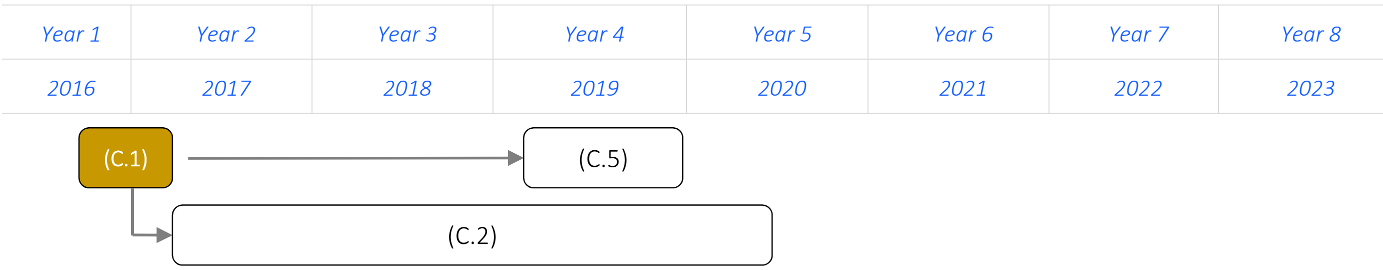
It is recommended that Metro continue to expand the pilot program to roll out on-board mobile gateway router technology for the rail fleet and that this router would become the primary data communications manager for all functions including passenger Wi-Fi, CAD/AVL, vehicle diagnostics, fare collection and video/security systems.

Determination of timing of the ATMS II implementation is critical, and if it is going to proceed in the near term, it is strongly recommended that the data communications for the rail system be implemented at the same time or completed before the ATMS II implementation. This project can be completed very quickly since the commercial cellular networks already exist.

The recommendations provided for the bus data communication system in Section 2.1.1 for a drive test, negotiations with both the cell providers and LA-RICS, backup systems, migration to 5G, and Connected Vehicle technology also apply to the rail data communication system project.

Implementation Schedule and Key Dependencies

Drive testing (shown as C.1 below) should be completed prior to the implementation of any communications system project, including C.2 and C.5 that establish cellular service for the Bus and Rail fleets.

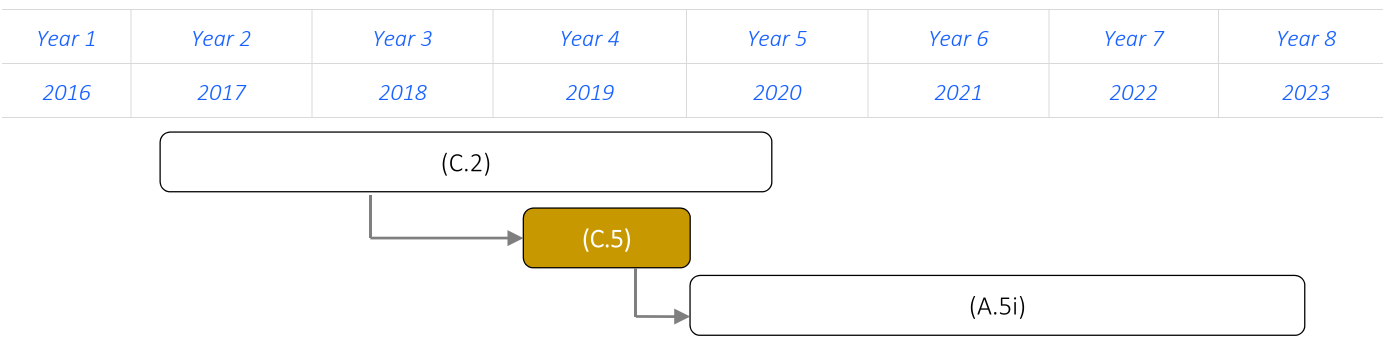


(C.1) Drive Test (cell + LA-RICS)

(C.2) Connected Vehicle: Establish (Commercial) Cellular Data Service for Bus Fleet

(C.5) Connected Vehicle: Establish (Commercial) Cellular Data Service for Rail Fleet

The timeline below illustrates the implementation of the cellular data network for rail communications, and its linkage to the cellular data network communications for bus and the ATMS II project.



(C.2) Connected Vehicle: Establish (Commercial) Cellular Data Service for Bus Fleet

(C.5) Connected Vehicle: Establish (Commercial) Cellular Data Service for Rail Fleet

(A.5i) ATMS II for Rail

2.1.1 Additional Communications System Recommendations

It is also recommended that Metro investigate LA-RICS' plans for tunnel LTE services. The radio system in the tunnels of the rail system will need to be revised to provide coverage for the LA County Sheriff when the LA-RICS LMR system is completed and the LA County Sheriff migrates onto it. Metro should also investigate if LA-RICS has plans to extend its LTE service into the rail tunnels. If the LTE network is going to

be extended into the tunnels to meet Public Safety agencies' communication needs, Metro might also be able to utilize this network for its data communications in the tunnels.

2.2 ATMS II Bus and Rail

The bus fleet currently utilizes ATMS to help manage its fleet operations. The Task 1 Needs Assessment identified significant needs to enhance, supplement, and/or replace the dispatching and operations control functionality of ATMS. In some cases, this simply involved streamlined reporting and new methods of more rapidly and effectively getting information from ATMS to related systems. In other cases, the needs were to support functions across modes (e.g. ability to coordinate bus bridges for rail operations). Task 1 identified the need to get the right data to the right people at the right time. In addition, the on-board ATMS subsystems and other subsystems are outdated, nearing end of life, and are in need of replacement/upgrade. An updated CAD system would include new tools to aid in service recovery. Including a new wireless data system with greater bandwidth than the current ATMS data system would help meet the need for more accurate vehicle location information and improved security if live video from a vehicle could be streamed on demand to the BOC.

The rail fleet operations does not currently utilize a CAD system. Rail controllers utilize the SCADA system to monitor train locations and store incident information in M3. There is no data communication system so controllers can only communicate with operators via a voice radio system. The Task 1 Needs Assessment identified needs for CAD tools for rail operations to improve logging incident information, provide data communications and a messaging system, improve the consistency and accuracy of information, and improve coordination of activities with bus operations for bus bridges. Including AVL capability with a CAD system would help meet the need to improve the reporting of train location information. Including a wireless data connection to the vehicles with an on-board CAD system would help meet the need to automate collection of vehicle data and save the time and costs of collecting the data manually, to provide enhanced easy to understand customer information on board the vehicles, and to provide improved security if live video from a vehicle could be streamed on demand to the ROC.

For the Task 3 alternatives analysis, Task 4 SWOT analysis, and Task 5 Cost Benefit Analysis, it was assumed that all of the CAD alternatives considered for bus operations would in general provide the features desired by Metro and would meet the needs identified in the needs assessment. The differentiators between the alternatives primarily were the costs, future proofing, and which alternative would best meet Metro's needs. For the CAD alternatives for rail operations, it was assumed that the first three alternatives would in general provide the features desired by Metro and would meet the needs identified in the needs assessment. The fourth alternative was scored lower in performance, risk, meeting agency needs, and future proofing because ARINC, the SCADA vendor for Metro, does not currently offer all of the CAD tools and features desired by Metro, while the CAD products offered by other vendors do.

The highest rated alternative from the assessment of CAD for bus operations and for rail operations was the same: procure and implement a new CAD system that supports both bus and rail operations. A single CAD/AVL system best meets LA Metro's needs--providing efficient and effective CAD tools for both bus and rail fleet operations and improved coordination between the bus and rail operations when there are situations such as bus bridges. Implementation of a single CAD/AVL system for both bus and rail operations is also more cost effective than implementing separate CAD systems for each. A number of transit agencies have implemented or are implementing joint CAD/AVL systems for their bus and rail fleets.

This project will begin with the development of a high level design and technical requirements for ATMS II Bus and Rail by a consultant. ATMS II would be procured using an open procurement. The ATMS II project should include implementation of the emerging onboard architecture that is recommended in Section 2.3.

The following paragraphs provide details of the recommended ATMS II Bus and Rail project.

ATMS II Bus and Rail

Projects: A.1, A.2, A.3, A.4, & A.5 + A.5i

This project involves an open procurement for a replacement of the ATMS CAD/AVL system for the bus fleet operations and to extend the new CAD/AVL system to support rail fleet operations. The new state-of-the-art CAD/AVL system would include new CAD workstations for the bus operations center (BOC), rail operations center (ROC), and Bus and Rail Divisions; servers; CAD software; and new on-board hardware for the buses, rail vehicles, and supervisor vehicles. The onboard hardware for the buses and rail vehicles include MDT, WLAN radio, GPS receiver and other AVL hardware, on-board processor, router; cellular modem; APCs; internal LCD signs for infotainment; interface to the farebox, headsigns, public address (PA) system, on-board video system, and on-board vehicle health monitoring systems; and county-wide signal priority capability. The vehicles for road supervisors and field supervisors will include a GPS receiver and other AVL hardware, cellular modem, and a removable laptop or tablet.

Some of the features of ATMS II include: interface to a cellular data network for VoIP communications and data communications with the fleet vehicles, vehicle location and schedule adherence tracking and reporting, vehicle location map displays and vehicle status displays, incident and event logging, automated onboard stop announcements and other passenger information, automatic passenger counting, silent alarm with covert microphone monitoring and streaming video, interface to the farebox for a single point logon and location tagging of fare transactions, automated display of route and destination information on headsigns, transit signal priority that conforms to the Countywide Signal Priority architecture, database to TDB interface, and robust report generator.

Benefits

- ATMS II with state-of-the-art CAD features would result **in improved effectiveness of the controllers** in managing bus operations and rail operations and resolving incidents. ATMS II will provide improved CAD tools for bus operations and a completely new set of CAD tools for rail operations. ATMS II will include tools that provide **more accurate vehicle location and vehicle data** such as passenger counts, vehicle health data, and onboard video during emergencies. ATMS II will provide improved map displays that will also provide traffic information, satellite and street level images. Other tools include more user friendly detour creation, increased electronic storage for previously created detour routes, forms and manuals, improved playback, spell check, bus bridge tool, arrival predictions, improved transfer protection between buses and bus and rail, and AI type recommendations for courses of action.
- For rail operations, ATMS II will provide a **new messaging capability** between controllers and operators that will reduce the amount of voice calls on the ICOM voice radio system.
- ATMS II's CAD tools will provide **greater efficiency in logging incident information** by BOC, ROC, Division, and supervisor personnel. ATMS will include **state of the art report generation**

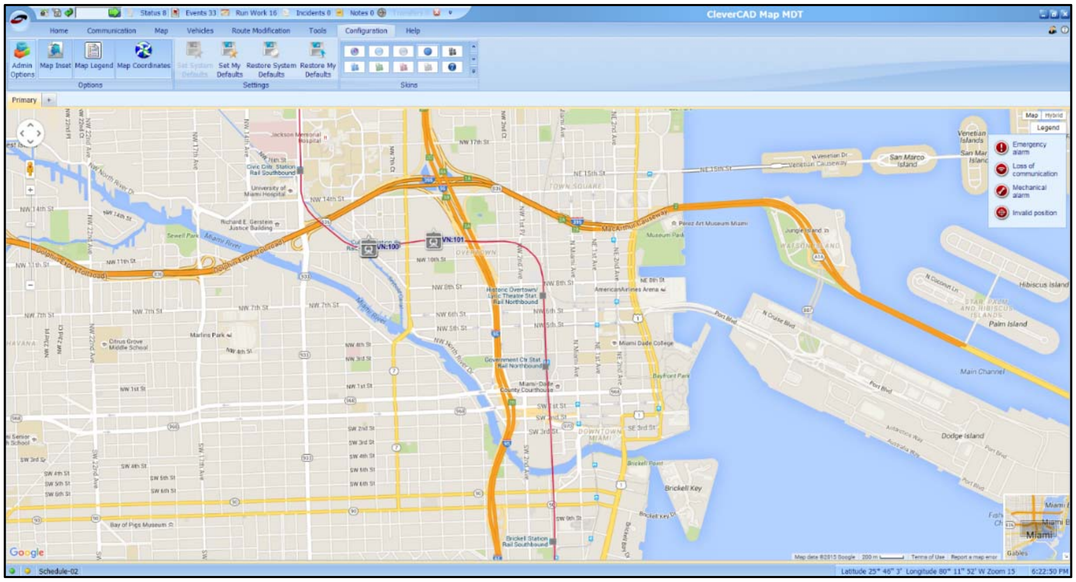
tools that will enable faster generation of fleet management reports and dashboard style reports for Division staff and supervisors.

- The ATMS II on-board system will result in improved effectiveness of the operators in communications with controllers, and logging data. The MDT will provide operators with a color touchscreen terminal with improved ability to view messages, log pre-trip information, view route information, and send canned messages.
- The ATMS II onboard router will enable the vehicles to have flexible communication paths. In case the cellular data network is unavailable, the router will switch bus voice communications from VoIP to the ATMS voice radio system. The router will enable data communications to switch to Wi-Fi when the vehicle is within range of a suitable WLAN network.
- State-of-the-art APCs will replace aging APCs and improve passenger count accuracy.
- ATMS II onboard LCD monitors will provide content rich passenger information including a list of the upcoming stops, general service announcements, and real-time alert information sent by the controllers. The PA system will provide similar audio information.
- The ATMS II onboard on-board system will enable vehicle health and other vehicle information to be automatically retrieved wirelessly.
- ATMS II will have new or improved interfaces to other IT systems such as M3, SCADA, HASTUS, and traveler information systems that would eliminate manual entry of data into the other IT systems.
- The ATMS II hardware will be more reliable and will replace aging ATMS hardware that is becoming increasingly difficult and costly to maintain.

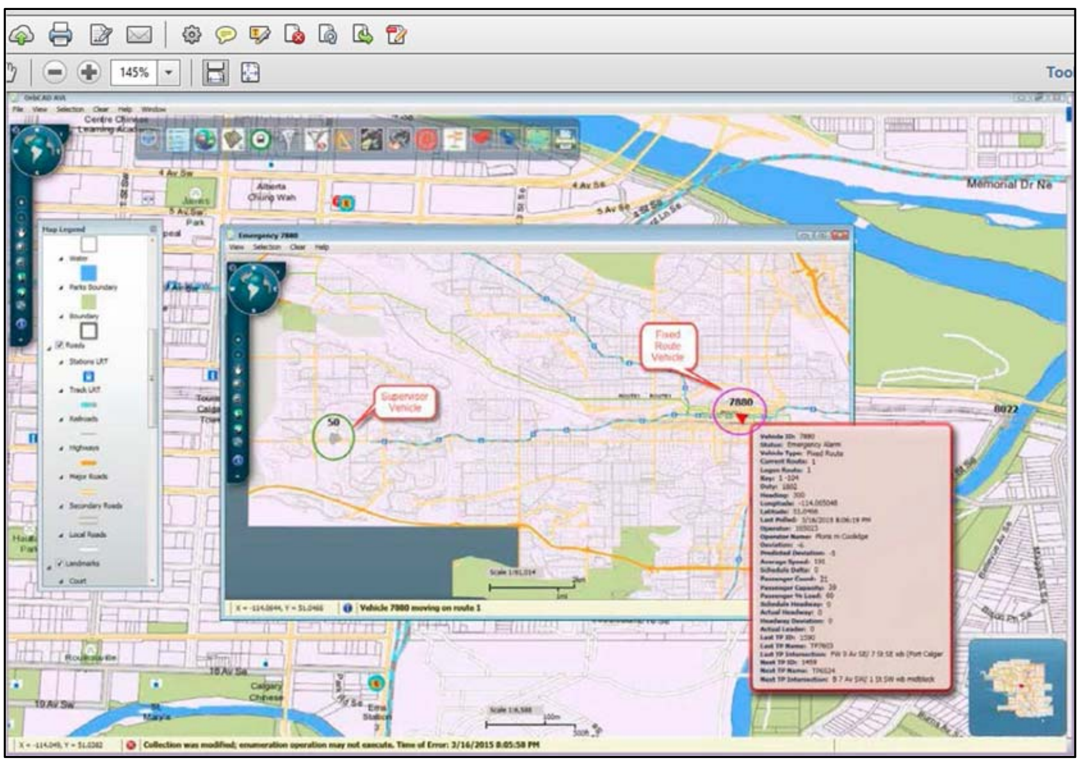
Technical Analysis Summary

ATMS II will replace the current ATMS CAD/AVL system that is nearing end of life. ATMS II will utilize state-of-the-art technology to enable more efficient operations, improved voice and data communications, improved accuracy in vehicle location reporting and time of arrival predictions, and improved CAD tools for Metro staff to manage incidents and to disseminate service changes and disruptions information to Metro’s ridership. Upgrade of the ATMS onboard components will enable Metro to migrate to a modern onboard architecture that will allow for flexibility in the communication systems used and flexibility in the addition of new onboard components.

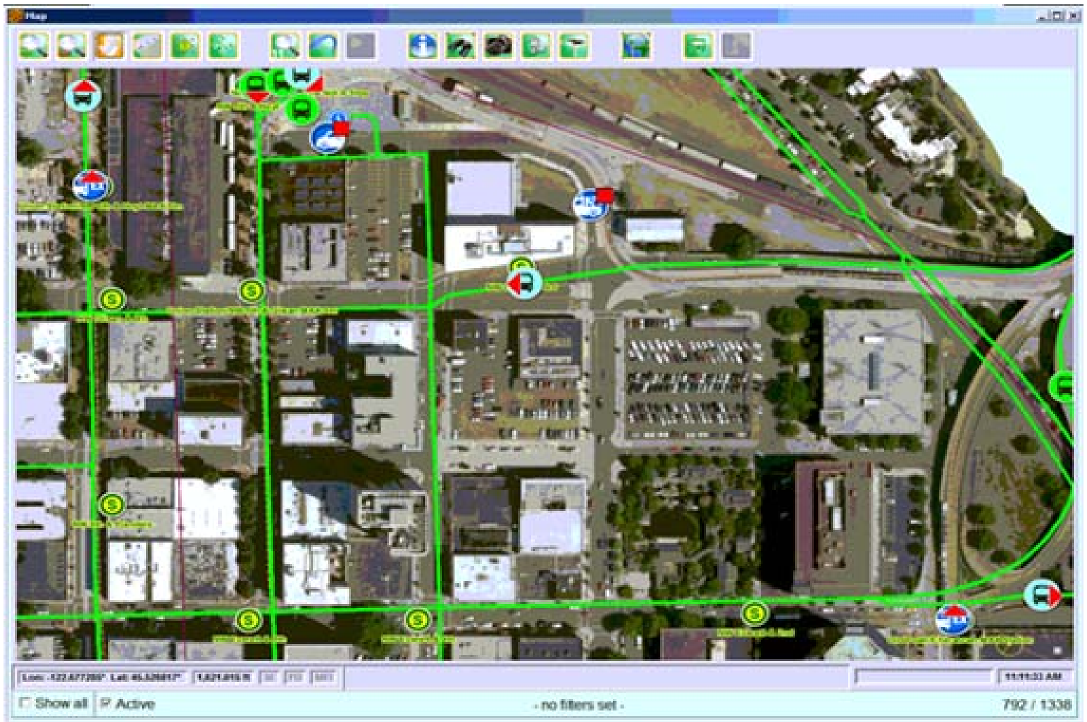
CAD operations will be more efficient because the controller will have more accurate and timely vehicle location information. Currently, bus locations are only updated every three minutes. The update rate will be reduced to 30 seconds or less when a cellular data network for the bus fleet is implemented in conjunction with ATMS II. Rail locations will also be updated every 30 seconds or less. ATMS II will provide map displays showing vehicle locations on street maps that will provide more detailed information than what is currently provided to the bus and rail controllers. The map displays will also provide vehicle status information, traffic conditions, and satellite images as shown in the examples below.



Example of Map Display Showing Real-time Rail Vehicle Locations

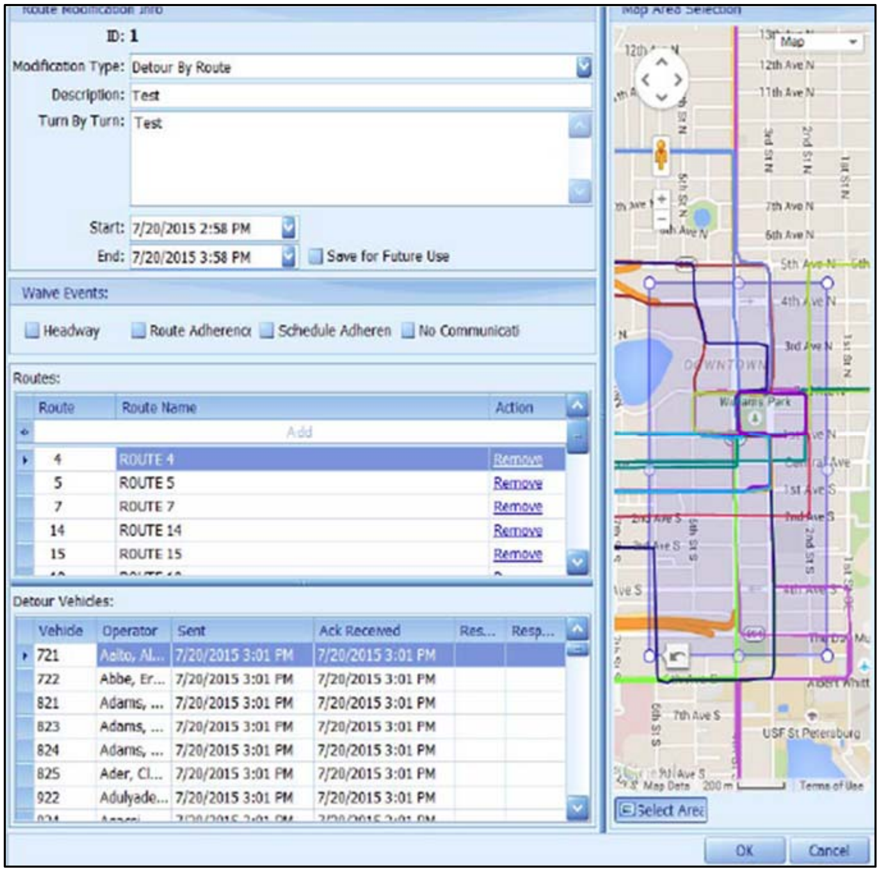


Example of Map Display Showing the Nearest Supervisor Vehicle to a Selected Bus



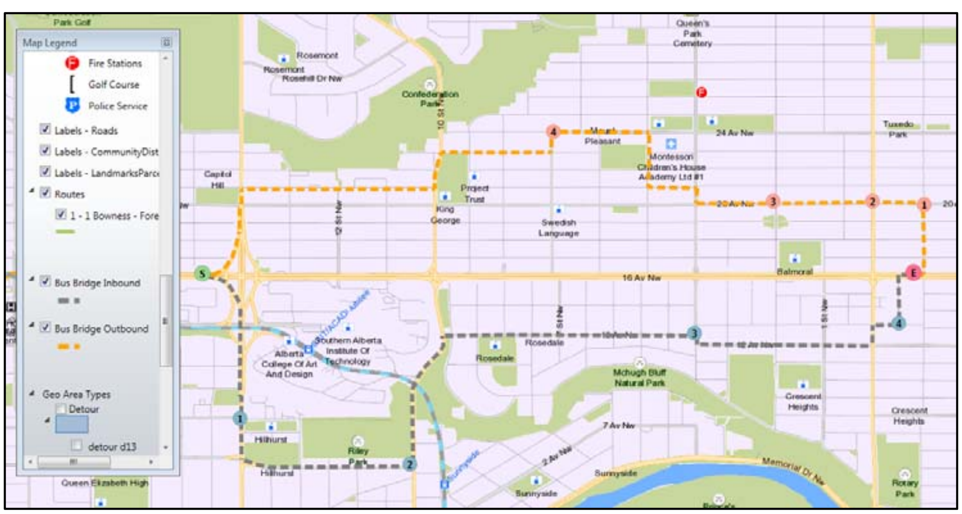
Example Map Display Showing the Display of Traffic Information

ATMS II will provide tools to aid controllers in managing incidents by automatically routing notifications to maintenance, alert systems, security and social media. Some CAD vendors offer decision making support features and alert notification features when there is a need for service adjustments. ATMS II will include interactive service adjustments tools and a user friendly tool for detour generation.



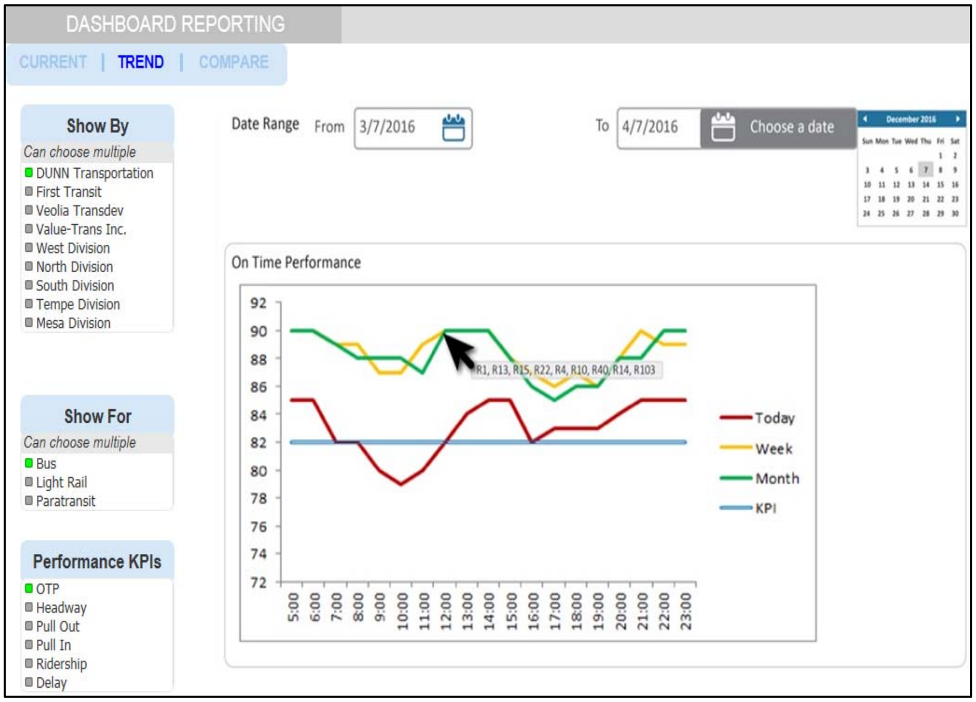
Example of a Modern CAD User Interface for Ad hoc Creation of Detours

Detour generation will be one of the tools provided by ATMS II to manage bus bridge incidents. Since both rail and bus operations will be using ATMS II, bus and rail vehicle locations will be provided to both operations as well as a connection protection tool.



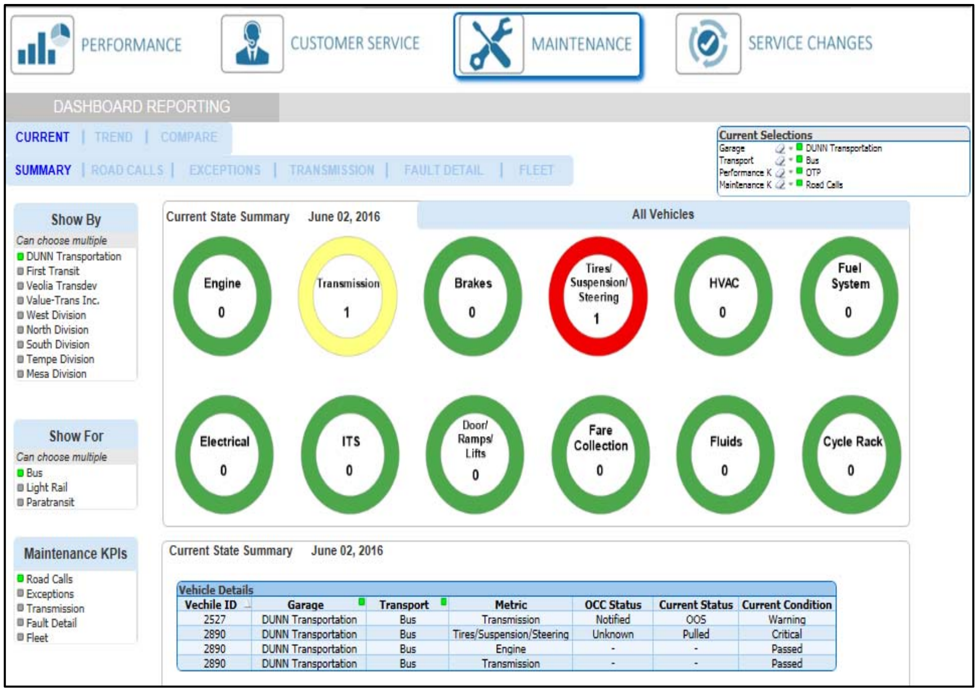
Example of a Modern CAD User Interface for Bus Bridges

ATMS II will include a logging tool to create electronic records of incidents that can be stored in a database. The data will be available for the generation of fleet management reports and dashboard summaries.



Example of a Business Intelligence Reporting Tool Interface

ATMS II will monitor the status of onboard equipment and provide real-time equipment alerts as well as data that can be used to schedule preventive maintenance.

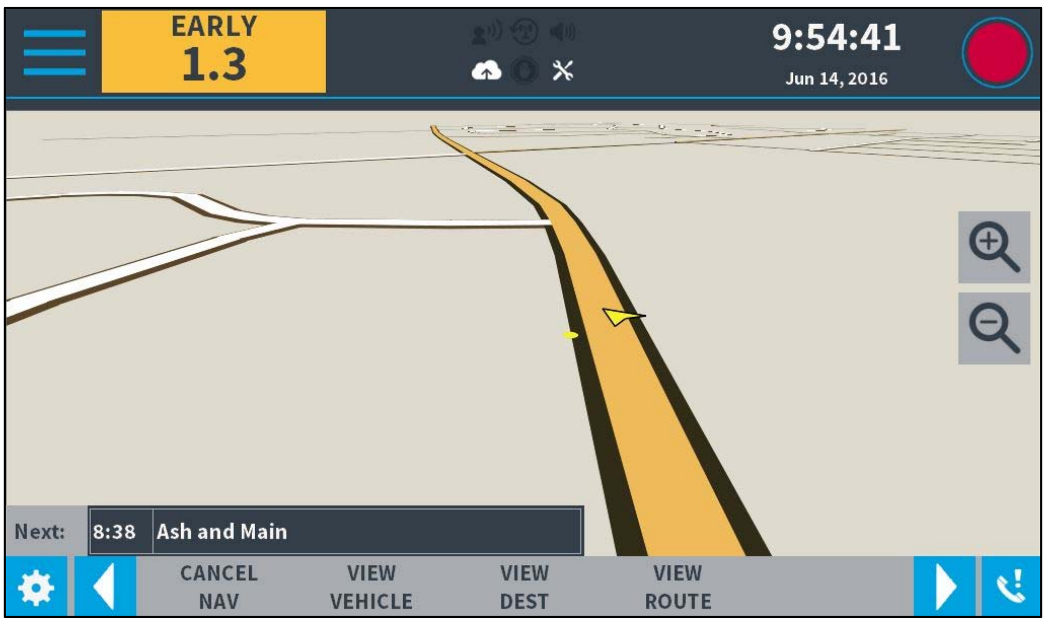


Example of a System Dashboard for Vehicle Health Monitoring

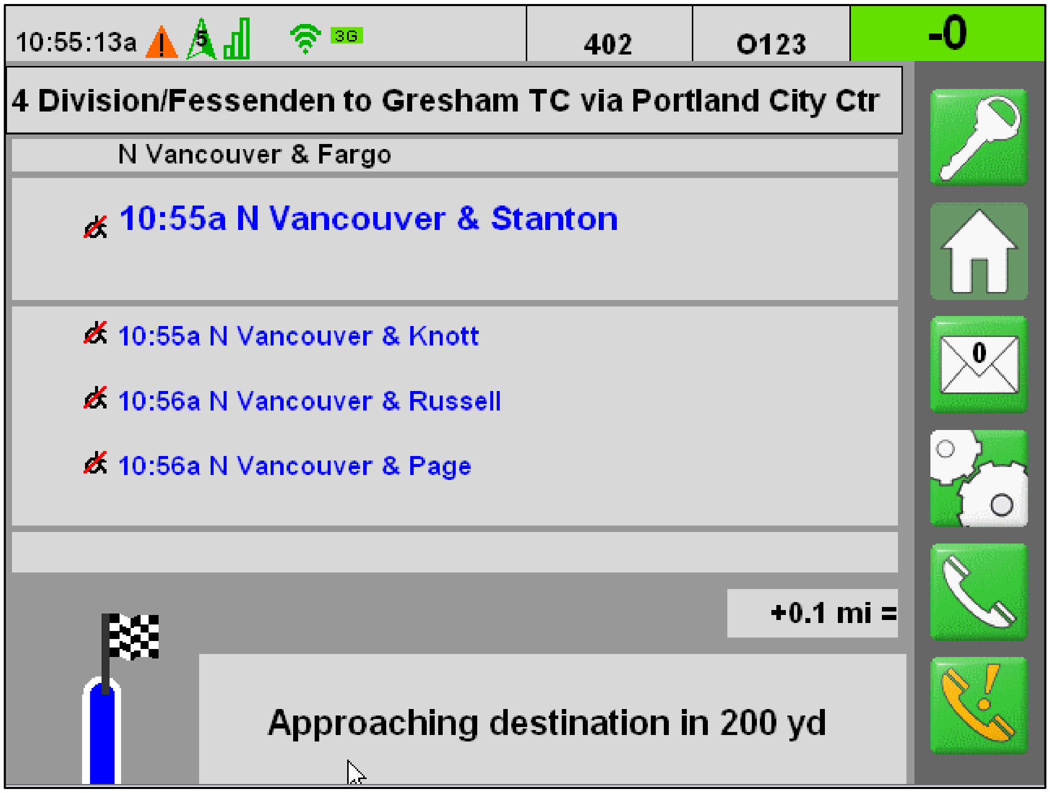
The ATMS II onboard equipment will consist of an onboard processor, color touchscreen MDT, automatic passenger counters, automatic voice annunciation and passenger infotainment LCD monitors, GPS receiver and other AVL hardware, mobile gateway router, WLAN radio, interfaces to the onboard video security system, headsigns and other onboard vehicle systems. On the buses, the ATMS II MDT will also provide a user interface for the farebox and the router will be configured to provide data communications for the farebox/TAP system. The onboard processor will calculate the vehicle's location and determine the vehicle's schedule and route adherence. The processor will also provide onboard TSP functionality that sends signal priority requests to signal controllers that conforms to the LA Countywide Signal Priority architecture.

The MDT will display schedule adherence information, text messages from controllers, and can show turn-by-turn directions for detours and bus bridges. The MDT will enable operators to log onto ATMS II and the farebox, send canned messages to controllers, record pre-trip information, and initiate public service announcements on the PA system and the onboard monitors.

Example of a Modern MDT Display.



Example of an MDT Display with Turn-By-Turn Navigation



Example of an MDT Display with Arrival Information

The recommended on-board architecture for the bus and rail fleets is discussed in greater detail in Section 2.3.

Benchmarking

A number of agencies have implemented or are planning to implement CAD/AVL systems that support both their bus and rail fleet operations including the SFMTA (San Francisco, CA), CapMetro (Austin, TX), VTA (San Jose, CA), SORTA (Cincinnati, OH), TriMet (Portland, OR), and SunTran (Tucson, AZ).

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
Bus: $68.3M	$29.3M
Rail: $24.1M	$14.8M

Additional cost break down information may be found in the ROM Section 5.

Assumptions

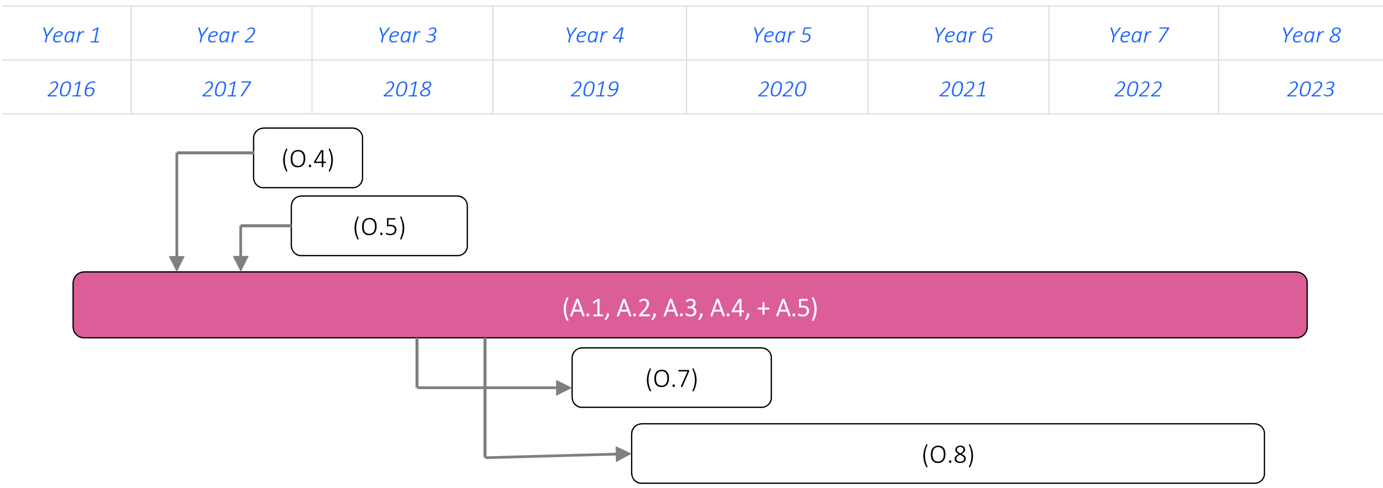
- ATMS II will be implemented in conjunction with the implementation of a cellular data network for data communications and VoIP for voice communications.
- Costs are based on ROMs received from CAD/AVL vendors.

- Capital costs include contractor project management costs for meetings, design reviews, training, acceptance tests, pre-acceptance system support, and performance bond; BOC, ROC, Division, and onboard vehicle hardware and software; manuals, design documents, and drawings.
- ATMS II planning, design, and implementation costs assume adoption of the Emerging Trends on-board systems architecture. Overall, adoption of this architecture should save future operations and system lifecycle costs by reducing equipment replacement and integration costs for new elements and functions.
- O&M costs include contractor provided hardware and software warranty support for 10 years.

Implementation Considerations

Some elements of ATMS II may be implemented in advance of the ATMS II backend. The timing of these early implementations would be based on ongoing projects and Metro needs. Implementation of the onboard router will most likely occur as part of the Connected Fleet Vehicles & Facilities project. The Connected Fleet Vehicles & Facilities project is a foundational element of adopting the recommended Emerging Trends on-board architecture. Implementation of other onboard components such as new APCs may occur in advance of the ATMS II implementation due to the age of the existing hardware. Some of the older onboard video systems may need to be upgraded to enable real-time video streaming as part of the ATMS II implementation. The ATMS II implementation may need to be delayed if it is determined that the ATMS II backend will be installed in the ESOC building. The recommended Emerging Trends on-board systems architecture should be recognized early in ATMS II planning and procurement, and be maintained over time as part of the larger Fleet and Communications Systems configuration management efforts.

Implementation Schedule and Key Dependencies



(O.4) Requirements for New/Transitional Onboard Architecture

(O.5) Fleetwide MGR (and cellular data) for Bus

(O.7) Fleetwide MGR (and cellular data) for Rail Vehicles

(O.8) Emerging Bus + Rail Architecture Implementation

A.X) ATMS II efforts::

(A.1) Planning and Approvals: 10/2016 To 3/2017

(A.2) Procurement of Project Support: 4/2017 To 12/2017

(A.3) Preparation for Procurement: 1/2018 To 6/2018

(A.4) ATMS II Procurement: 7/2018 To 3/2019

(A.5) ATMS II Implementation – Bus: 4/2019 To 8/2023

(A.5i) ATMS II Implementation – Rail: 4/2020 to 8/2023

Relationship to On-board Architecture Recommendations

As part of the ATMS II project efforts for bus and rail, it is recommended that a new on-board architecture be adopted to support: less dependency on a single vendor, improved on-board communications options, improved compatibility between certain bus and rail technologies, on-board Ethernet/IP network connectivity, and improved project lifecycle for equipment/components and lower integration costs over time. Implementing and sustaining this new on-board architecture will take some addition effort during ATMS II planning, procurement, and testing, notably:

- Specifying a more open on-board architecture standard for ATMS II, leveraging the Connected Fleet Vehicles & Facilities project as a foundation.
- Requiring the selected ATMS II vendor to demonstrate multi-make and model compatibility for on-board equipment-- particularly the MDT and IVU/VLU given a specific operating system and functionality set. In addition, equipment compatibility should be demonstrated across the bus and rail fleets.
- Ensuring that open platform compatibility testing is conducted at multiple stages of the ATMS II deployment, and deploying multiple makes and models of key equipment elements. The goal is to ensure Metro does not become "stranded" with a non-industry standard device that cannot be easily transitioned to newer equipment.
- Work with the contractor to establish a "configuration baseline" with all of the necessary details to enter into, manage, and maintain configuration management for a minimum period of 10-15 years.

Long-term ATMS II Recommendations

The following are some recommendations to be implemented in the future:

- Re-examine communication options when 5G and 6G becomes available.
- Replace or upgrade CAD system after 10 years.
- Replace or upgrade all servers after 5 years.

2.3 On-board Architecture

Historically, on-board architectures have centered on one or more IVU/VLUs that offer proprietary integration to other devices (e.g., APCs, AVA, DVRs, etc.). This integration has been expensive and time consuming, and has often led to agencies effectively deploying multiple IVU/VLUs on a vehicle to avoid the integration costs. Changes in the mobile/automotive computing hardware and software market are starting to break down these proprietary barriers to integration. Where common public transit data standards may not exist, the consumer electronics and automotive original equipment manufacturers (OEM) industries are stepping in and "selecting de facto standards" for their own purposes. The benefits of these trends are starting to open up new possibilities for transit agencies looking to update/deploy new on-board equipment and update their architecture approaches. These trends look to a more open hardware environment, particularly for the IVU/VLU and MGR components on the vehicles, where integration and interfaces will not be a priority. The mobile data terminal (MDT) shifts to being a display device on the on-board Ethernet/IP network and the IVU/VLU becomes a platform running a selected operating system (OS) much like the competitive procurement environment for workstation and server hardware. Following this trend creates an architecture that is more open and allows agencies to more readily transition mobile hardware and components without being beholden to a single vendor. While not fully mature in the transit environment, outside forces in the mobile computing world are ensuring this trend is certain to continue.

The following sections describe the recommendations for the bus and rail fleet on-board architectures. The table below provides an overview of the sequenced on-board architecture projects comprising the recommendations for both the bus and rail fleet solutions to best support the technology program outlined in this Plan, along with some key current/ongoing and planned projects impacting the on-board architecture recommendations. They also represent the best options for leveraging other solutions implemented under the program that will result in cost savings and reduced timelines for implementation. Note that some elements represent shared projects between bus and rail. The recommended projects and approach to implementation are described in greater detail in the following bus and rail fleet sections.

ON-BOARD ARCHITECTURE FOR BUS AND RAIL FLEETS PLANNED AND RECOMMENDED PROJECTS SUMMARY	
O.2 *Expand Router to 500 Vehicles (Connected Bus)*	Part of Connected Bus & Facilities efforts; its costs are not included in on-board architecture cost estimates, but included in existing projects and/or ATMS II.
O.3 *Emerging Bus/Rail Architecture Planning/Requirements*	Early stages of agency planning and development of new on-board architecture – included in on-board architecture costs. Note this should be conducted cooperatively between bus and rail to establish which architecture elements should be common fleet-wide and which are bus or rail specific.
O.4 *Requirements for New/Transitional On-Board Architecture*	Early, more detailed planning and early implementation to ensure transitional stage for bus on-board architecture is consistent with what is established as part of project element O.3.

O.5 Fleetwide MGR (and cellular data) for Bus	Period of confirmation if project C.2 is moving forward or if the MGR and cellular data implementation will be part of the ATMS II implementation. Note that the timeline for C.2 and O.5 may vary, but the Connected Bus and Facility efforts are assumed to be in place by ATMS II or they would have to be combined into that project effort.
O.6 Automated Passenger Counter (APC) Project	It is anticipated that the APC systems on-board buses will be updated prior to the ATMS II implementation. This means that APC replacement systems should demonstrate compatibility with the emerging trends architecture and the ability to communicate through the MGR.
O.7 Fleetwide MGR (and cellular data) for Rail	As part of the larger Connected Fleet Vehicles & Facilities project, rail vehicle would be receiving MGRs with associated cellular data and Wi-Fi connectivity. APC and VSS, as well as live video feeds would be supported through this component of the on-board architecture.
O.8 Emerging Bus + Rail Architecture Implementation	The actual implementation of the on-board architecture will occur as part of the ATMS II implementation (A.5).
O.10 On-Board Systems Configuration Management	Once the on-board architecture is established and in implementation as part of ATMS II, it is important to enter configuration management for the on-board architecture, requirements, and interfaces to ensure long-term effectiveness and consistency.
O.11 Review & Refresh Bus + Rail On-Board Architecture	By 2025 Metro should review the status of the on-board architecture and determined if any adjustments or changes are required.

Three ranges of emerging on-board technology trends were evaluated for this Strategic Plan, including: current technology trends, emerging trends, and future trends. Given the timelines anticipated for the connected bus, ATMS II, and related projects, the emerging trends was selected as the baseline for the new on-board Metro systems architecture.

2.3.1 Bus Fleet On-board Architecture

On-Board Systems Architecture – Bus (Emerging Trends)
Projects: O.2, O.3, O.4, O.5, O.6, O.8, & O.10

This project sees the implementation of an emerging-trends based on-board architecture as part of the ATMS II project and as described in detail in the Implementation Considerations sub-section below.

Benefits

- **Improved data communications with vehicle** and updated on-board systems - including removal of MDT limitations. Easier future integration and swapping of on-board equipment.
- A major advantage of this approach is that it **allows Metro to transition, replace, and upgrade key on-board devices without proprietary hardware/interface limitations**.
- **Strong potential for equipment and integration cost savings** for minimal costs when compared with the costs of fleet-wide equipment/device replacements in combination with new central system integration.
- **Eliminates direct ties to a single vendor** where Metro is unable to update on-board hardware/software without expending well above anticipated levels.

Technical Analysis Summary

The emerging trends architecture was primarily recommended for the following reasons:

- It is an excellent fit with Metro's proposed Connected Fleet Vehicles & Facilities project efforts which would deploy Mobile Gateway Routers (MGRs) on the entire bus fleet. In addition, Metro's latest bus procurement specification includes a substantially capable MGR requirement. These provide the foundational elements of the emerging trends architecture.
- Metro's stated desire is to be consistent with emerging technologies, but not to necessarily incur the risks of "bleeding edge developments" which tends to rule out the future trends architecture which is more fully device to device and Internet of Things (IoT) based. This environment has not matured nearly to the same extent as the emerging trends architecture.
- The emerging trends on-board architecture overcomes some of Metro's past difficulties of integration to a single proprietary platform, including becoming locked into utilizing outmoded Mobile Data Terminals (MDTs) that cannot be replaced or upgrades without a complete system upgrade.
- The emerging trends architecture provides a solid foundation to advance the state-of-the-fleet on-board as new functions and devices emerge over time through promotion of a common on-board Ethernet/IP network with a common MGR as a mobile communications platform that can evolve as communications needs and opportunities shift over time.

The implementation section discusses more of the device by device implications on board the bus.

Benchmarking

The use of a MGR as a common communications platform on board the bus is now standard practice for new fleet system procurement efforts. On-board Ethernet/IP environments have been implemented by TriMet (Portland), RTD (Denver), AC Transit (Oakland), Foothill Transit (LA), and many others across North America. The extent of the individual device integration to the on-board Ethernet/IP environment varies by implementation, but frequently includes: MDTs, APCs, camera systems, IVUs/VLUs, and on-board customer information displays. Devices are starting to emerge that would support Ethernet/IP for vehicle health monitoring, headsign displays, etc.

Cost Summary

The costs of adopting the emerging trends on-board architecture is largely additive to the ATMS II project in terms of increased architecture and configuration management costs in terms of agency staff support, increased testing and design costs for the initial ATMS II implementation efforts, and some minor costs for additional equipment/devices to test cross-compatibility between different IVUs and MDTs.

CAPITAL COSTS	O&M COSTS (10yr)
$ 2.4M*	$ 1.2M**

**Over planning and implementation period for ATMS II*

***Costs mostly staff related for architecture and configuration management as new devices/systems emerge on board the vehicles.*

Additional cost break down information may be found in the ROM Section 5.

Assumptions

- Metro will continue to move forward with its Connected Fleet Vehicles & Facilities project efforts, ultimately leading to all buses having MGR implementations (either through retrofits or new bus procurements).
- The use of commercial cellular data or similar (e.g. LA RICS data) is assumed as LMR systems would be unable to adequately support the data communications loads envisioned from the MGR and other devices on the bus.
- Metro will coordinate all new bus on-board device procurements to be consistent with the on-board architecture. This may require some additional planning and work up front, but will dramatically lower risks and costs over time as equipment ages, is replaced, or compatibility needs to be maintained as new vehicles are procured.

Implementation Considerations

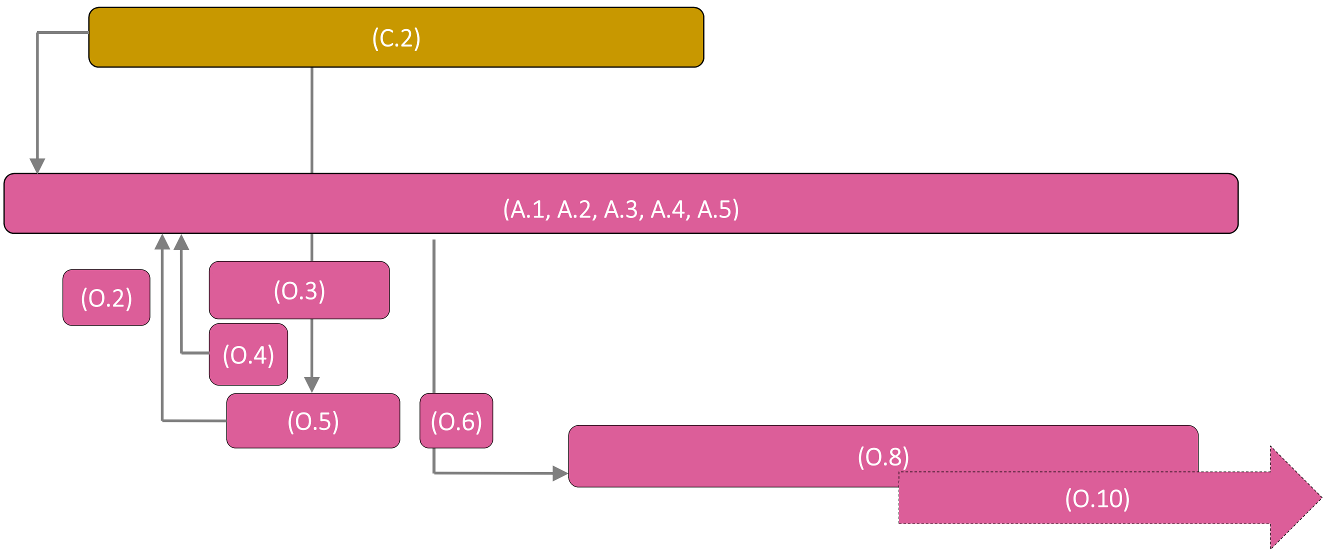
There will be some key decisions to be made as the development and implementation of the on-board architecture proceeds:

- It is not sufficient to standardize on an Ethernet/IP communications platform on-board. Metro will need to make more detailed architecture decisions such as the on-board IVU operating system. Individual on-board device applications may be integrated with the open IVU/VLU platform or run as an application on the IVU/VLU itself. The goal would be to allow multiple vendor applications to operate on the IVU/VLU without the need for proprietary integration efforts by the IVU/VLU vendor. This is similar to running different devices or applications on and connected to a typical PC computing platform.
- Additional testing will be required to prove that the IVU/VLU and MDTs are truly an open platform and that the same ATMS II applications can run on multiple devices from different suppliers. While this may seem like unnecessary additional effort up-front, it helps to demonstrate the necessary flexibility of the on-board devices and helps ensure future compatibility and upgrade paths are retained.
- The priority of devices and communications on-board the bus needs to be determined. Devices such as automated fare collection systems (including smart cards and mobile payments), camera systems, and data/voice communications are normally prioritized at the highest level through the MGR settings/configuration.
- Metro will need to establish an on-board systems configuration management group(s) to deal with on-board network configuration, devices/settings, requirements for new procurements, and ensuring adjustments/changes don't have unanticipated consequences. This group could include bus and rail agency staff in a combined configuration management effort.
- The current pool of CAD/AVL vendors may be resistant to supplying a more open IVU/VLU and on-board architecture in an effort to maintain a single supplier proprietary relationship with Metro. However, a review of hardware and software development platforms in use by these vendors indicates that this goal should be more than achievable within the timeframe of the ATMS II planning and implementation. Just as consumers are no longer willing to accept smartphones that can only run apps from a single company, the transit industry should no longer accept IVUs/VLUs that are essentially proprietary devices.

Implementation Schedule and Key Dependencies

The on-board bus architecture effort is strongly tied to the ATMS II and the Connected Fleet Vehicles & Facilities projects. Initial architecture requirements must be confirmed and basic on-board configuration management put in place as part of ATMS II planning and procurement. The timeline below provides a snapshot of the recommended on-board bus architecture projects and related projects

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*



(C.2) Connected Vehicle: Establish (Commercial) Cellular Data Service for Bus Fleet

(O.2) Expand Router for 500 vehicles (Connected Bus)

(O.3) Emerging Bus + Rail Architecture Planning/Requirements

(O.4) Requirements for New/Transitional Onboard Architecture

(O.5) Fleetwide MGR (and cellular data) for Bus

(O.7) Fleetwide MGR (and cellular data) for Rail

(O.8) Emerging Bus + Rail Architecture Implementation

(O.10) On-board Systems Configuration Management

(A.X) ATMS II efforts::

(A.1) Planning and Approvals: 10/2016 To 3/2017

(A.2) Procurement of Project Support: 4/2017 To 12/2017

(A.3) Preparation for Procurement: 1/2018 To 6/2018

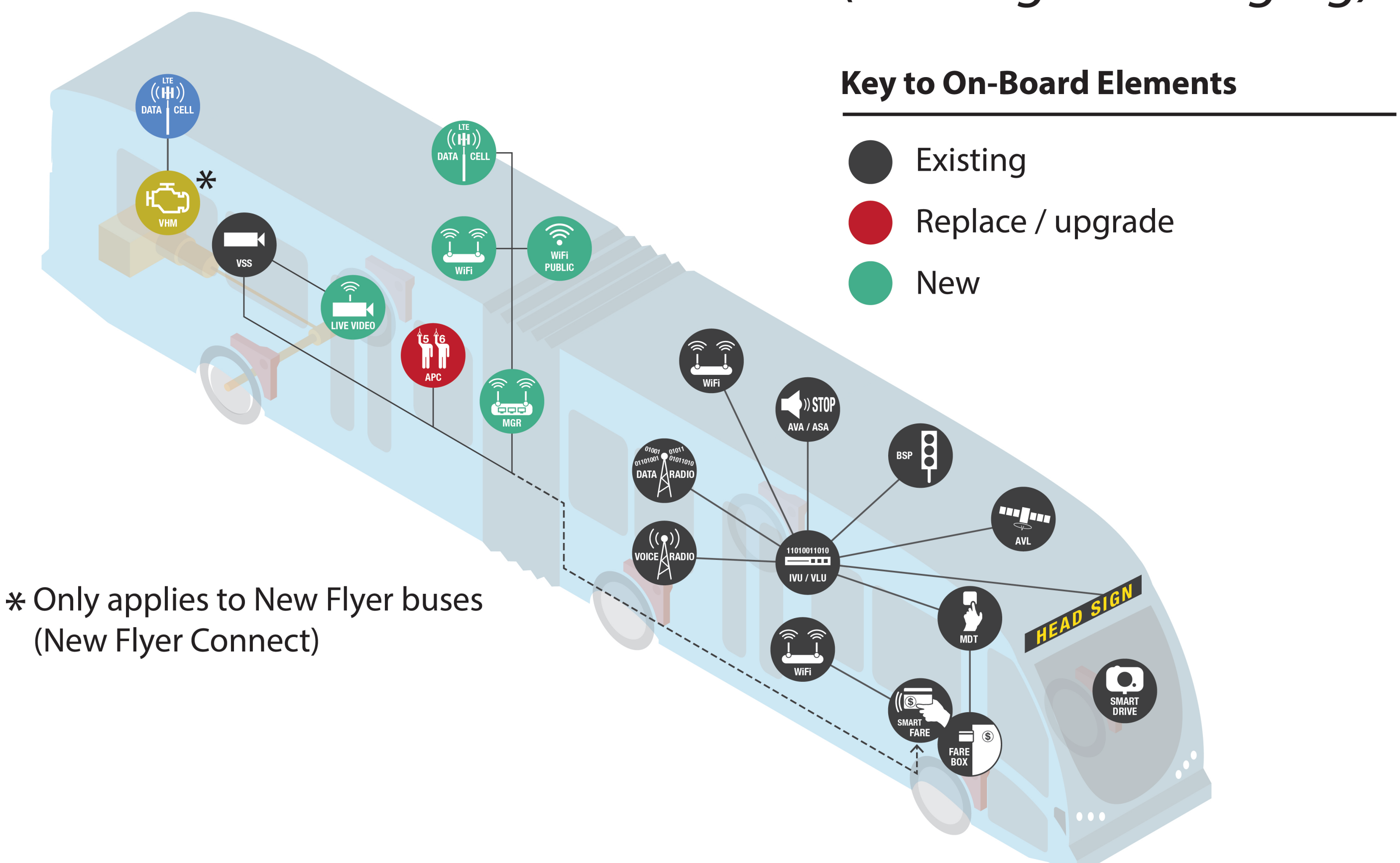
(A.4) ATMS II Procurement: 7/2018 To 3/2019

(A.5) ATMS II Implementation – Bus: 4/2019 To 8/2023

(A.6) ATMS II Implementation – Rail: 4/2020 to 8/2023

The figures below display the recommended on-board architecture for the bus that is consistent with emerging trends in the transit industry. The first figure shows the onboard architecture of a bus with a transitional architecture. The second figure shows the recommended emerging trends on-board architecture. The table that follows the second figure discusses the architecture implications of each on-board device.

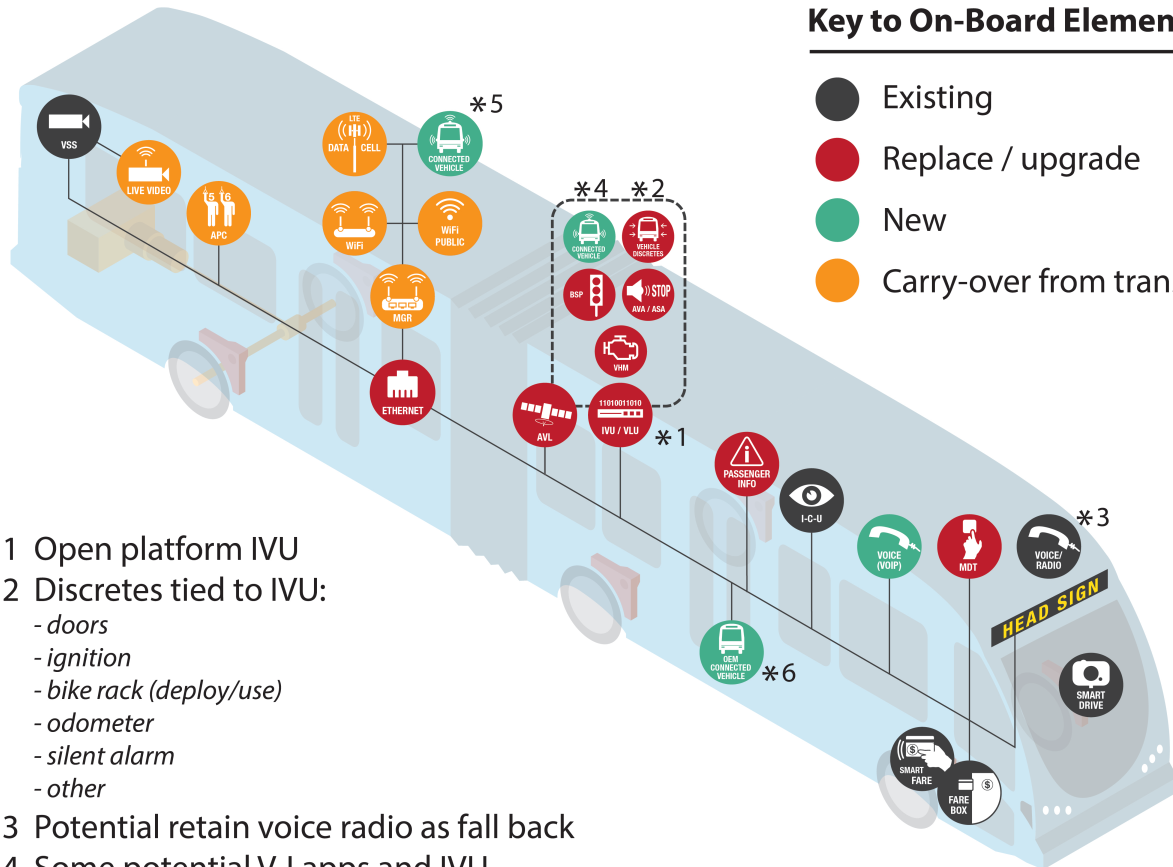
Transition Stage Bus
(Existing to Emerging)



Emerging Bus

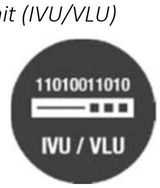
Key to On-Board Elements

- Existing
- Replace / upgrade
- New
- Carry-over from transitional stage



*1 Open platform IVU
*2 Discretes tied to IVU:
- *doors*
- *ignition*
- *bike rack (deploy/use)*
- *odometer*
- *silent alarm*
- *other*

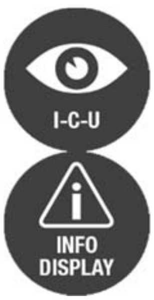
*3 Potential retain voice radio as fall back
*4 Some potential V-I apps and IVU
*5 Connected vehicle communications through on-board network
*6 OEM connected vehicle (safety/autonomy) functions on separate on-board network with alarms and data bridged to MGR network

ON-BOARD DEVICE	NOTES ON INTEGRATION INTO EMERGING ON-BOARD ARCHITECTURE
Intelligent Vehicle Unit/Vehicle Logic Unit (IVU/VLU) 	In the emerging architecture, the IVU/VLU will remain a core on-board computing platform, but must be proven to be non-proprietary. The selected ATMS II vendor software must be capable of operating on multiple IVU/VLU devices from different manufacturers as well as being capable of running third party applications for other on-board devices (such as vehicle health monitoring, Bus Signal Priority, and possibly others. Metro will need to select an operating system for the new IVU/VLU that will remain common regardless of the hardware utilized. The processing and capabilities of the IVU/VLU procured through ATMS II should allow for future growth and integration of other on-board devices over time.

ON-BOARD DEVICE	NOTES ON INTEGRATION INTO EMERGING ON-BOARD ARCHITECTURE
Mobile Data Terminal (MDT) 	The emerging architecture calls for an MDT that is effectively a touch/input device with a multipurpose LCD/similar display. Basic audio and auto light adjustments should also be in place. The MDT should be directly connected to the on-board Ethernet/IP network without separate or additional proprietary connections to the IVU/VLU. The goal is that the MDT should be able to be replaced (as partial fleet upgrades) without the need to upgrade or change the IVU/VLU. In addition, as part of the ATMS II deployment, the vendor should be able to demonstrate at least three different MDT makes and models that can perform the necessary on-board functions. While this will require extra diligence and testing during the ATMS II deployment, it is critical as this has been a problematic area for Metro in the past where MDTs become difficult to maintain or replace.
Automated Video/Stop Announcements (AVA/ASA) 	Currently AVA and ASA functions are integrated with the IVU/VLU. This could remain the case for the new architecture and the ATMS II implementation. However, a more open IVU/VLU should allow for independent AVA/ASA systems that are not necessarily tied to the primary ATMS II vendor. This also offers the opportunity for ADA supporting functionality or improved AVA/ASA technology enhancements to be added over time leveraging the open IVU/VLU platform and the communications functionality of the MGR for both customer based (e.g. smartphone, ADA device) or on-board functions.
Vehicle Health Monitoring (VHM) 	There is limited VHM functionality currently deployed (e.g. New Flyer Connect as an example) in the vehicle fleet and it is independent from other on-board systems. Enhanced VHM functionality and integration is highly desired and could be run on the open IVU/VLU platform with deployment either as part of ATMS II implementation or separately. The VHM communications should be integrated through the MGR for both Wi-Fi and mobile data.
Vehicle Discrete 	For the foreseeable future and as part of the ATMS II implementation, some vehicle discretes will need to be maintained and integrated. For example, ignition status, bike rack deployment, ADA ramp deployment, etc. Discrete connections should be maintained separate from the IVU/VLU box to maintain the flexibility of swapping that device or updating over time. Discretes could be connected through backplanes or terminal blocks. Power down timers should be managed through the IVU/VLU or the MGR as derived from the ignition status.
Bus Signal Priority (BSP) 	Bus Signal Priority is being integrated with the current ATMS IVU/VLU, and it is assumed that this functionality will be carried over to ATMS II when it is deployed. The major change would be that the BSP communications should ultimately be routed through the MGR either as Wi-Fi, DSRC, or other.

ON-BOARD DEVICE	NOTES ON INTEGRATION INTO EMERGING ON-BOARD ARCHITECTURE
Connected Vehicles	At this point, the full range of Connected Vehicle functionality is not defined, but it will clearly impact the on-board bus architecture and related functionality in several areas. For the emerging on-board architecture, it is envisioned that CV applications will fall into three categories/areas: • *Original Equipment Manufacturer (OEM) Connected Vehicles* – These are Autonomous Vehicle and Connected Vehicle functions that would be procured with new buses over time. These would largely be safety or guidance based functions that would be part of the vehicle manufacturer's production, integration, and safety integrity level (SIL) assessments. While these systems might provide status or alerts to the remainder of the on-board architecture, for safety reasons they would largely remain independent from the remainder of on-board fleet systems. • *Connected Vehicle Communications* – Largely centered on Dedicated Short Range Communications (DSRC) in the 5.9GHz range. It is envisioned that these communications functions will ultimately be internal to or integrated with the MGR. Some specialized Autonomous Vehicle (AV) functions may retain separate DSRC communications. • *Connected Vehicle Applications Running On-Board* – In addition to the OEM and CV communications specific functionality, some CV functions call for on-board computing power and integration with other fleet management systems. These functions could be supported by the open IVU/VLU platform for options such as flex routing, shared ride coordination, or other Vehicle-Infrastructure CV applications.
Automatic Vehicle Location (AVL)	AVL functionality should be accurate enough to support all location needs on the bus and should be able to provide AVL data to all other on-board elements without the need for additional or separate GPS antennas or AVL systems. This can also serve as a common on-board time source. Sometimes AVL functionality is integrated into the MGR and/or the IVU/VLU, but in either event, the ability of it to provide common AVL data for the vehicle should be demonstrated.
Mobile Gateway Router (MGR)	The MGR would be provided through multiple means: new bus procurements, Connected Fleet Vehicles & Facilities project, and ultimately ATMS II if required. The MGR is the foundational element of the on-board architecture and serves to extend an IT/network type environment onto the bus. The MGR allows for multiple modes of communications, prioritization of communications, a single point for communications upgrades/adjustments, switching between various on-board communications options based on configurable rules, and an improved method of monitoring communications of the mobile fleet. The MGR usually is directly connected to some key devices as part of the on-board network, and a separate switch provides additional Ethernet ports (usually 8+). This means that priority devices must typically be connected to ports directly on the MGR or on a managed switch connected to the MGR.
Ethernet/IP On-Board Connectivity	As part of the Connected Fleet Vehicles & Facilities project, as well as ATMS II, the on-board bus architecture should move towards all devices being Ethernet/IP capable. All devices should be connected to the on-board network through the MGR or associated switches, and not directly to the IVU/VLU. Some specific discrete connections (such as ignition status, etc.) may be retained to the IVU/VLU, but these should be limited and reduced over time.

ON-BOARD DEVICE	NOTES ON INTEGRATION INTO EMERGING ON-BOARD ARCHITECTURE
Cellular Data	The recommended data communications options for Metro is cellular data through either commercial sources or LA-RICS. Cellular data communications serves as the primary means of mobile data communications from the bus. The MGR should be capable of supporting either or even both data communications networks.
Voice Communications (VoIP with possible radio fallback)	The Communications Plan recommends VoIP communications as the primary voice communications means for bus. VOIP can be setup for RTT/PRTT type communications methods used by the BOC. It is important to note that VOIP occurs over cellular data which is distinct from the cellular voice network which is more likely to become overloaded during emergency situations. VOIP functionality is most frequently implemented as a separate VOIP card or device on the bus which is integrated with the IVU/VLU and MDT to emulate the RTT/PRTT functionality. In some cases, VOIP functionality might be integrated with the IVU/VLU which should be carefully reviewed to ensure that this does not compromise the IVU/VLU as being an open platform moving forward. The existing voice radio system could be retained for fallback/redundancy purposes. The existing voice radio system could be converted to open talkgroups as fallback or integrated directly as a fallback solution with the VOIP controller.
Wi-Fi Communications (Agency & Public)	Metro intends to provide public Wi-Fi access on some vehicles/routes and this is an element of the Connected Fleet Vehicles and Facilities project that would deploy MGRs on bus and ultimately rail vehicles. In addition, the MGR will need to support agency Wi-Fi communications needs for the upload/download of data from various systems on-board the vehicles. Options for using cellular data for all of these functions were reviewed, but proved cost-prohibitive. All Wi-Fi communications should be routed through the MGR regardless of whether the on-board device is directly integrated with the IVU/VLU or not.
Automated Passenger Counters (APCs)	Metro intends that APCs will be replaced during the transitional stage of the on-board architecture, and may proceed the ATMS II implementation. This means that the APC sensors and analyzer will be independent of the IVU/VLU. To maintain architecture consistency and avoid potential integration issues down the road, APC logic should be deployed on an open platform with an on-board operating system consistent with the IVU/VLU operating system. This should leave the opportunity to move the APC applications and functionality to the IVU/VLU in the future should Metro desire to do so.

ON-BOARD DEVICE	NOTES ON INTEGRATION INTO EMERGING ON-BOARD ARCHITECTURE
Video Surveillance System (VSS) & Live Video Feeds 	Currently Metro buses are deployed with a range of makes/models/ages of on-board surveillance systems. As part of the emerging architecture, all VSS on-board fleet vehicles should be Ethernet/IP capable and be connected to the on-board network and MGR. Newer DVRs that are part of the VSS have 2TB of storage to support Metro video retention requirements. Ultimately, once the Connected Fleet Vehicles and Facilities projects are complete and the DIMS and video storage efforts done, it may not be necessary to maintain such substantial storage on-board the vehicles. All video (with sound) downloads, uploads, and live feed access should be communicated through the MGR with the MGR providing QoS and prioritization functionality. Only some Metro VSS are capable of live video feeds, but this should become a standard requirement for all new and replacement systems, as it was viewed as a high priority need. ATMS II costs include some % of VSS replacements on the existing fleet to meet this standard. It is not intended that the architecture support full time live video feeds from a large number of vehicles, and live feeds would be focused on emergency or special situations with a selected group of operations, security, and law enforcement staff having the ability to activate live feeds.
I-See-U Monitor & Passenger Info Display 	Metro has had good success with providing a monitor on-board buses that demonstrates to passengers that security cameras are present on the bus and video is being recorded. These are known as "ICU" systems. For the emerging architecture, the ICU display should be part of the on-board Ethernet/IP network, although video feeds might stem directly from the DVR which is part of the VSS. In addition, the architecture supports a separate LCD or similar customer on-board information display that could obtain base data through yard downloads with lower bandwidth data updates through cellular. All of this would be conducted through the MGR. Also, the ICU and Info Display could be merged to displays on-board live video as well as traveler information such as service alerts, bus position/map, connecting status and anticipated arrival at key locations.
Smart Drive 	SmartDrive is currently an independent system on Metro buses and rail vehicles. Its primary focus is for incident surveillance and risk management where certain G-forces and other situations trigger video saving and download for basic on-board and outside front views. SmartDrive is highly valued by Metro for these functions and the ease of accessing the stored/tagged video. It will remain separate as part of the new on-board architecture for the foreseeable future.
Farebox & Smartcard (TAP) 	The on-board farebox and smart card (TAP) system are anticipated to receive updates over the life of the new on-board architecture. Key to the TAP updates is the desire to allow account values and updates (such as new or recharged TAP cards) to be quickly recognized on the buses. Currently these changes may take 2-3 days to appear. The new on-board architecture assumes updated communications will be integrated from the smart card through the MGR cellular data connection. It should be possible to support desired security without a separate independent cellular connection. The actual software/configuration changes for TAP would be part of a separate project effort. This connection between the smartcard and the MGR/cellular communications could occur during the transitional stage (after the MGR/Connected Fleet Vehicle projects but prior to full ATMS II implementation). Ultimately, should a farebox/smartcard be retained in the longer-term, the separate wireless communications should be integrated through the MGR.

2.3.2 Rail Fleet On-board Architecture (Emerging Trends)

The recommended rail on-board architecture included some unique elements due to the diverse character of the systems and level of integration of the existing Metro vehicle fleet. As with bus, three ranges of emerging on-board technology trends were evaluated for this Strategic Plan, including: current technology trends, emerging trends, and future trends. The desire was to establish some elements of fleet-wide commonality for the on-board architecture while recognizing the elements unique to rail, as well as the role track wayside and SCADA systems play in managing and controlling rail operations. The goal was for the on-board rail architecture to establish some commonality for like elements, but supplement or support existing track wayside and rail control systems rather than replace them over time (as was the case with bus elements). As part of the Strategic Plan program elements, rail vehicles could receive the initial MGR and cellular data connectivity through the Connected Fleet Vehicles and Facility project and/or as part of ATMS II.

Currently, the rail vehicles lack consistent on-board device integration for VSS/DVR, Wi-Fi connectivity, AVA/ASA, and APC where these exist. Individual systems are often procured with the rail vehicles themselves or outfitted at the time the rail line is implemented. Several rail vehicles have unique train separation/spacing control systems that work in conjunction with the track wayside communications.

While some elements of rail on-board architectures remain unique to the make and model of the rail vehicle, many other supplemental communications and customer information elements can be part of the broader on-board fleet vehicle architecture. For Metro, the advantage rail vehicles have in updating the on-board architecture, is that they are not as subject to the past decisions and existing systems as rail technologies have tended to be track-to-wayside based with limited on-board equipment. The common fleet on-board architecture elements for rail vehicles would include: MGR with Wi-Fi and cellular data communications, VSS/live video, passenger info displays, IVU/VLU, and MDT. Other train specific elements would remain independent of the new on-board architecture such as train protection (ATP), rail worker safety (ProTran), rail voice radio, track wayside (TWC), smart drive, and rail specific traction, power and related systems. Some agencies are looking at methods to use newer on-board communications and architectures (as recommended in this Plan) to provide key train system alerts from braking, power traction, and power management subsystems. As with the bus architecture, the emerging on-board architecture for rail looks to a more open hardware environment, particularly for the IVU/VLU and MGR components on the vehicles, where integration and interfaces will not be a priority. The mobile data terminal (MDT) shifts to being a display device on the on-board Ethernet/IP network and the IVU/VLU becomes a platform running a selected operating system (OS) much like the competitive procurement environment for workstation and server hardware. Following this trend creates an architecture that is more open and allows agencies to more readily transition mobile hardware and components without being beholden to a single vendor. While not fully mature in the transit environment, outside forces in the mobile computing world are ensuring this trend is certain to continue.

On-Board Systems Architecture – Rail (Emerging Trends)
Projects: O.3, O.4, O.5, O.7, O.8, & O.10

For this project, Metro will implement the emerging trends-based on-board architecture as described in greater detail in the Implementation Considerations sub-section below. This will follow the same sequence as described in the on-board architecture section introduction.

Benefits

- Improved data communications with vehicle and updated on-board systems. Easier future integration and swapping of on-board equipment.
- A major advantage of this approach is to allow Metro to transition, replace, and upgrade key on-board devices without proprietary hardware/interface limitations.
- Commonality between some on-board elements and the architecture of the bus and rail vehicle fleets will result in economies of scale and simplify future upgrade paths, as well as support easier back office integration of rail and bus data for customer information and operations applications.
- Strong potential for equipment and integration cost savings for minimal costs when compared with the costs of fleet-wide equipment/device replacements in combination with new central system integration.
- Eliminates direct ties to a single vendor where Metro is unable to update on-board hardware/software without expending well above anticipated levels.

Technical Analysis Summary

The emerging trends architecture was primarily recommended for the following reasons:

- It is an excellent fit with Metro's proposed Connected Fleet Vehicles & Facilities project efforts which would deploy Mobile Gateway Routers (MGRs) on the entire rail. Rail vehicles turn-over far less frequently than buses, which means that retrofits are much more likely than simply capturing the new architecture in vehicle turn-over.
- Metro's stated desire is to be consistent with emerging technologies, but not to necessarily incur the risks of "bleeding edge developments" which tends to rule out the future trends architecture which is more fully device to device and Internet of Things (IoT) based. This environment has not matured nearly to the same extent as the emerging trends architecture.
- The emerging trends on-board architecture for rail vehicles allows for Metro to much more cost-effectively implement rail specific functionality using the open IVU/VLU platform, MGR communications, and the MDT. Proper implementation of this architecture as part of ATMS II will support future rail functional enhancements without being tied to a specific vendor.
- The emerging trends architecture provides a solid foundation to advance the state-of-the-fleet on-board as new functions and devices emerge over time through promotion of a common on-board Ethernet/IP network with a common MGR as a mobile communications platform that can evolve as communications needs and opportunities shift over time.

The implementation section discusses more of the device by device implications on board rail vehicles.

Benchmarking

While the use of a MGR as a common communications platform on board the bus is now standard practice for new fleet system procurement efforts, it is just now becoming more common on rail vehicles. Early implementation of MGRs on rail vehicles have been used to provide enhanced GPS/communications for rail arrival prediction and customer information applications. MBTA implemented a "rail hardened MGR" on their Green Line rail vehicles for enhanced rail vehicle positioning and schedule arrival prediction. TriMet recently initiated a procurement for a Mobile IoT Gateway specification to support a

variety of rail specific functions including on-board schedule adherence displays, arrival prediction improvements, and enhanced rail controller/operator text communications (the advantage of text communications through a rail MDT is that it can remain inactive/inaccessible when the vehicle is in motion).

Cost Summary

Rail vehicle inclusion is an option as part of ATMS II. Therefore, the costs of adopting the emerging trends on-board architecture is largely additive to the ATMS II project in terms of: increased architecture and configuration management costs in terms of agency staff support, increased testing and design costs for the initial ATMS II implementation efforts and some minor costs for additional equipment/devices to test cross-compatibility between different IVUs and MDTs.

CAPITAL COSTS	O&M COSTS (10yr)
$ 1.2M*	$ 874K**

**During the planning and implementation period for ATMS II*

***Costs mostly staff related for architecture and configuration management as new devices/systems emerge on board the vehicles.*

Additional cost break down information may be found in the ROM Section 5.

Assumptions

- Metro will continue to move forward with its Connected Fleet Vehicle & Facilities project efforts, ultimately leading to all rail vehicles having MGR implementations (either through retrofits or new bus procurements).
- The use of commercial cellular data or similar (e.g. LA RICS data) is assumed as LMR systems would be unable to adequately support the data communications loads envisioned from the MGR and other devices on the rail vehicle. As part of the communications plan, FluidMesh and other options were reviewed and seemed to offer some potential. Any such solution should be integrated with the on-board architecture through the MGR.
- Metro will coordinate all new rail on-board device procurements to be consistent with the on-board architecture. This may require some additional planning work up front, but will dramatically lower risks and costs over time as equipment ages and is replaced, or compatibility needs to be maintained as new vehicles are procured.

Implementation Considerations

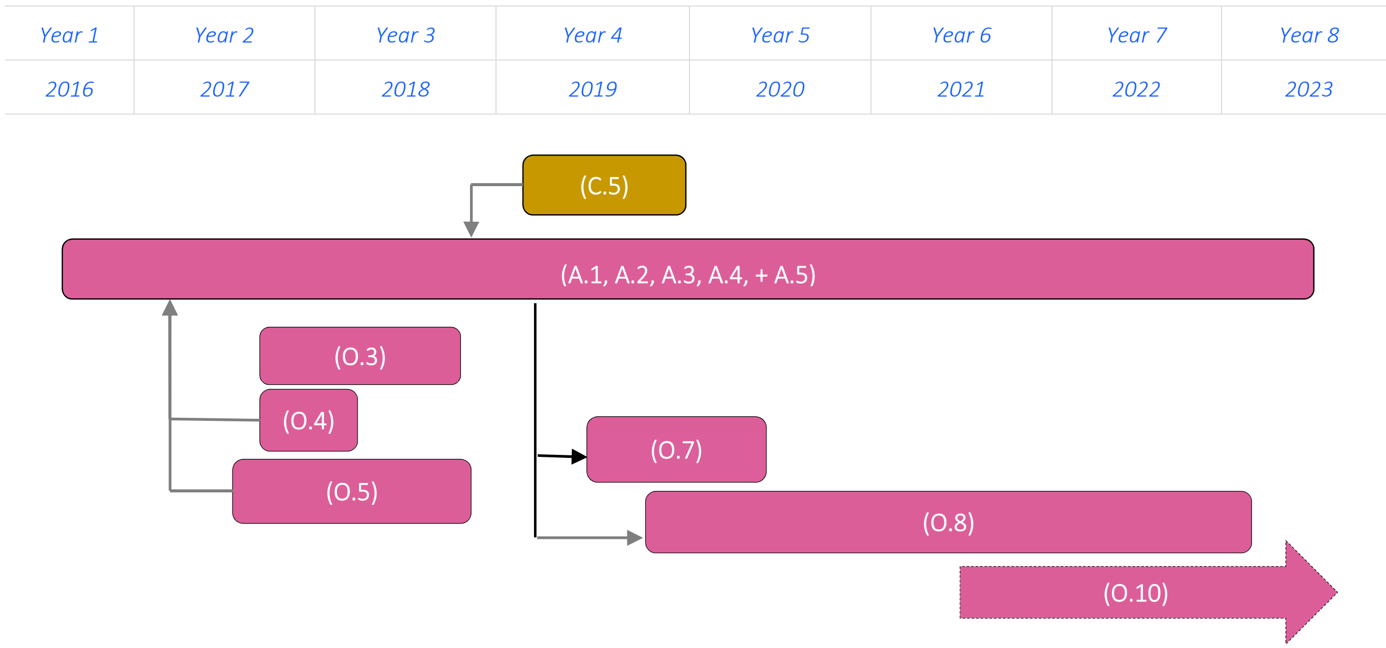
There will be some key decisions to be made as the development and implementation of the on-board architecture proceeds:

- It is not sufficient to standardize on an Ethernet/IP communications platform on-board. Metro will need to make more detailed architecture decisions, including the on-board IVU operating system. Individual on-board device applications may be integrated with the open IVU/VLU platform or run as an application on the IVU/VLU itself. The goal would be to allow multiple vendor applications to operate on the IVU/VLU without the need for proprietary integration efforts by the IVU/VLU vendor. This is similar to running different devices or applications on and connected to a typical PC computing platform.

- The recommended on-board architecture opens up several opportunities to integrate or enhance rail specific functionality. This could include communications across train consists, yard management functions, and specific rail operations support functions. Metro should consider implementing at least one of these rail specific functions as a separate effort from ATMS II procurement as a proof of concept for the open IVU/VLU platform.
- Additional testing will be required to prove that the IVU/VLU and MDTs are truly an open platform and that the same ATMS II applications can run on multiple devices from different suppliers. While this may seem like unnecessary additional effort up-front, it helps to demonstrate the necessary flexibility of the on-board devices and helps ensure future compatibility and upgrade paths are retained.
- The priority of devices and communications on-board the rail vehicle needs to be worked out. Usually devices such as smartcards, camera systems, and data/voice communications are prioritized at the highest level through the MGR settings/configuration.
- Metro will need to establish an on-board systems configuration management group(s) to deal with on-board network configuration, devices/settings, requirements for new procurements, and ensuring adjustments/changes don't have unanticipated consequences. This group could include bus and rail agency staff in a combined configuration management effort.
- The current pool of fleet system vendors may be resistant to supplying a more open IVU/VLU and on-board architecture in an effort to maintain a single supplier proprietary relationship, but a review of hardware and software development platforms in use by these vendors indicates that this goal should be more than achievable within the timeframe of the ATMS II planning and implementation. Just as consumers are no longer willing to accept smartphones that can only run apps from a single company, the transit industry should no longer accept IVUs/VLUs that are essentially fully proprietary devices.

Implementation Schedule and Key Dependencies

The on-board rail architecture effort is strongly tied to the ATMS II and Connected Fleet Vehicle & Facilities projects. Initial architecture requirements must be confirmed and basic on-board configuration management put in place as part of ATMS II planning and procurement. The timeline below provides a snapshot of the on-board rail architecture elements, as well as some related project efforts.



(C.5) Connected Vehicle: Establish (Commercial) Cellular Data Service for Rail Fleet

(O.3) Emerging Bus + Rail Architecture Planning/Requirements

(O.4) Requirements for New/Transitional Onboard Architecture

(O.5) Fleetwide MGR (and cellular data) for Bus

(O.7) Fleetwide MGR (and cellular data) for Rail

(O.8) Emerging Bus + Rail Architecture Implementation

(O.10) On-board Systems Configuration Management

(A.X) ATMS II efforts::

(A.1) Planning and Approvals: 10/2016 To 3/2017

(A.2) Procurement of Project Support: 4/2017 To 12/2017

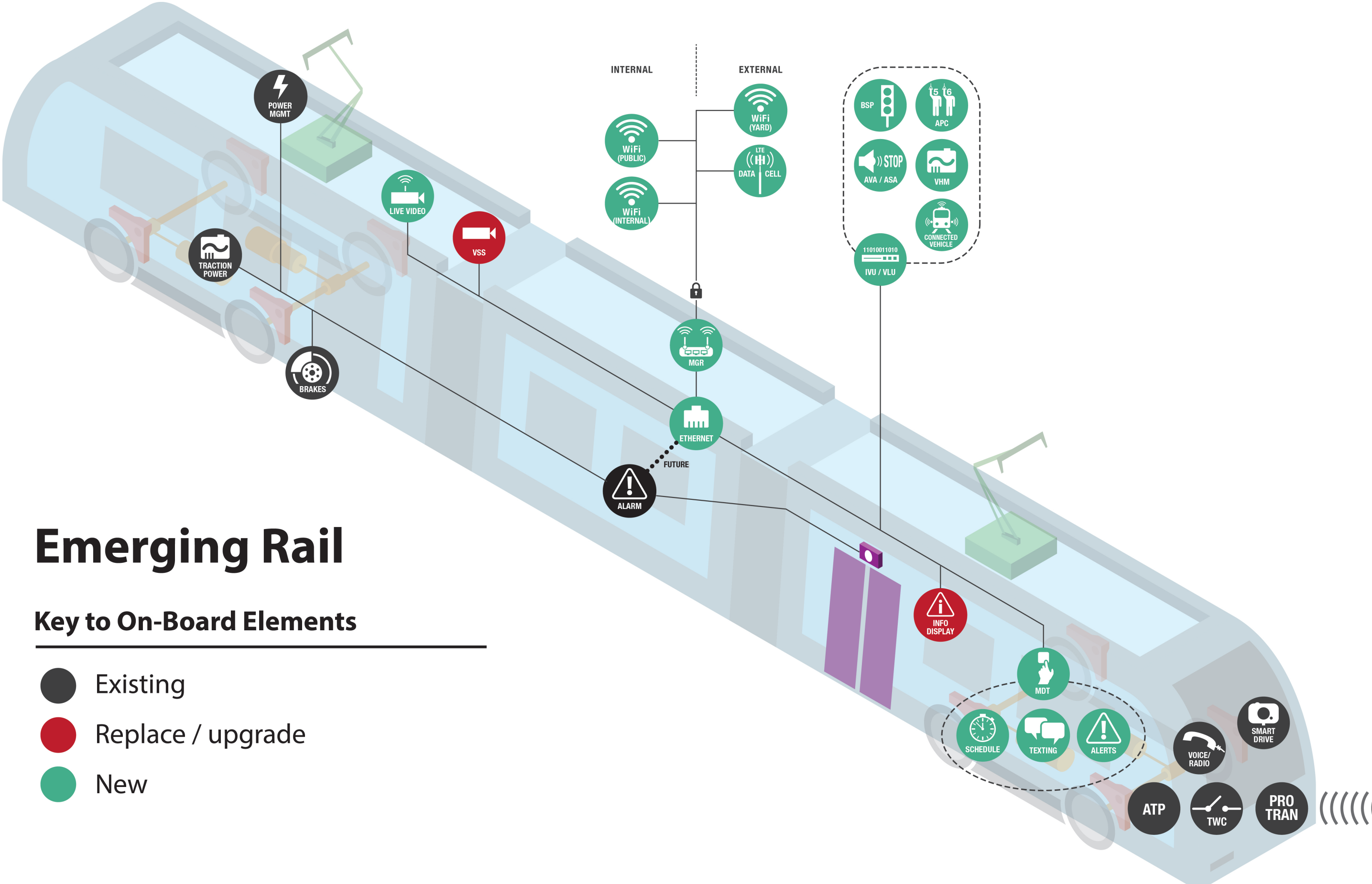
(A.3) Preparation for Procurement: 1/2018 To 6/2018

(A.4) ATMS II Procurement: 7/2018 To 3/2019

(A.5) ATMS II Implementation – Bus: 4/2019 To 8/2023

(A.6) ATMS II Implementation – Rail: 4/2020 to 8/2023

The figure below displays the recommended emerging trends on-board architecture that is consistent with emerging trends in the transit industry. The table that follows the figure discusses the architecture implications of each on-board device.



Emerging Rail

Key to On-Board Elements

- Existing
- Replace / upgrade
- New

ON-BOARD DEVICE	NOTES ON INTEGRATION INTO EMERGING ON-BOARD ARCHITECTURE
Intelligent Vehicle Unit/Vehicle Logic Unit (IVU/VLU) 	In the emerging architecture IVU/VLU will remain a core on-board computing platform, but must be proven to be non-proprietary with the selected ATMS II vendor software capable of operating on multiple IVU/VLU devices from different manufacturers as well as being capable of running third party applications for other on-board devices (such as vehicle health monitoring, Transit Signal Priority, and possibly others. Metro will need to select an operating system for the new IVU/VLU that will remain common regardless of the hardware utilized. The processing and capabilities of the IVU/VLU procured through ATMS II should allow for future growth and integration of other on-board devices over time.
Mobile Data Terminal (MDT) 	The emerging architecture calls for an MDT that is effectively a touch/input device with a multipurpose LCD/similar display. Basic audio and auto light adjustments should also be in place. The MDT should be directly connected to the on-board Ethernet/IP network without separate or additional proprietary connections to the IVU/VLU. The goal is that the MDT should be able to be replaced (as partial fleet upgrades) without the need to upgrade or change the IVU/VLU. In addition, as part of the ATMS II deployment, the vendor should be able to demonstrate at least three different MDT makes and models that can perform the necessary on-board functions. While this will require extra diligence and testing during the ATMS II deployment, it is critical as this has been a problematic area for Metro in the past where MDTs become difficult to maintain or replace. For the rail vehicles, the MDT would bring enhanced functionality including schedule adherence display (based on back-end rail location and prediction data), controller/operator text messaging, and vehicle status alerts.

ON-BOARD DEVICE	NOTES ON INTEGRATION INTO EMERGING ON-BOARD ARCHITECTURE
Automated Video/ Stop Announcements (AVA/ASA) 	AVA and ASA systems are largely unique to each line and this makes updates difficult in a rapidly shifting technology world. The new architecture would standardize and update these functions, allowing fleet-wide enhancements without the need for wholesale equipment replacement.
Vehicle Health Monitoring (VHM) 	VHM data on rail vehicles is difficult to obtain and requires extensive manual processes. The new on-board architecture would support enhanced rail specific VHM functions through the IVU/VLU and communications through the MGR to yard and rail maintenance and reporting systems. Key alerts on on-board devices, as well as rail specific system alerts (where available) could be integrated into this platform.
Bus Signal Priority (BSP) 	Bus Signal Priority is being integrated with the current ATMS IVU/VLU, and it is assumed that this functionality will be carried over to ATMS II when it is deployed. The major change would be that the BSP communications should ultimately be routed through the MGR either as Wi-Fi, DSRC, or other. It is envisioned that this functionality could be implemented for some rail vehicles similar to what is planned for buses.
Connected Vehicles 	At this point, the full range of Connected Vehicle functionality is not defined, but it will clearly impact the on-board bus architecture and related functionality in several areas. For the emerging on-board architecture on rail vehicles, this might include safety functions and customer information supporting functions, as well as others. The connected vehicle functions could be integrated into the IVU/VLU and communicated through the MGR or DSRC.
Automatic Vehicle Location (AVL) 	AVL functionality should be accurate enough to supplement rail vehicle location data combined with the TWC and SCADA systems.
Mobile Gateway Router (MGR) 	The MGR would be provided through multiple means: new rail vehicle procurements, Connected Fleet Vehicles & Facilities project, and ultimately ATMS II if required. The MGR is the foundational element of the on-board architecture and serves to extend an IT/network type environment onto the rail vehicle. The MGR allows for multiple modes of communications, prioritization of communications, a single point for communications upgrades/adjustments, switching between various on-board communications options based on configurable rules, and an improved method of monitoring communications of the mobile fleet. The MGR usually is directly connected to some key devices as part of the on-board network, and a separate switch provides additional Ethernet ports (usually 8+). This means that priority devices must typically be connected to ports directly on the MGR or on a managed switch connected to the MGR.

ON-BOARD DEVICE	NOTES ON INTEGRATION INTO EMERGING ON-BOARD ARCHITECTURE
Alerts & On-Board Train Systems Integration	The new on-board architecture offers the opportunity to integrate key "operational impacting" alerts into a more robust and widespread communications platform. These alerts could be immediately sent to rail operators (via MDT), rail controllers, maintenance personnel, and others as needed. These alerts could also be stored and integrated with yard and maintenance management systems through the new on-board architecture. Siemens is offering an integrated on-board train systems management and alerting unit that is an example of a device that could provide alerts through the new on-board architecture. Other examples would become available as newer rail vehicles are procured or updated. It should be noted that in the architecture, this connection is shown as "future" and would probably not be viable or cost-effective for the oldest rail vehicles in the Metro fleet.
Ethernet/IP On-Board Connectivity	As part of the Connected Fleet Vehicles & Facilities project, as well as ATMS II, the on-board bus architecture should move towards all devices being Ethernet/IP capable. All devices should be connected to the on-board network through the MGR or associated switches, and not directly to the IVU/VLU. Some specific discrete connections (such as ignition status, etc.) may be retained to the IVU/VLU, but these should be limited and reduced over time.
Cellular Data	The recommended data communication options for Metro is cellular data through either commercial sources or LA RICS. Cellular data communication serves as the primary means of mobile data communication from the rail vehicle. The MGR should be capable of supporting either or even both data communication networks.
Voice Communications (remains separate)	The Communications Plan recommends rail voice communications would remain as a separate system independent from the rest of the on-board architecture. This system was recently updated and can be expanded to support rail fleet expansion over the lifespan of the Strategic Plan.
Wi-Fi Communications (Agency & Public)	Metro intends to provide public Wi-Fi access on some vehicles/routes and this is an element of the Connected Fleet Vehicles and Facilities project that would deploy MGRs on rail vehicles. In addition, the MGR will need to support agency Wi-Fi communications needs for the upload/download of data from various systems on-board the vehicles. Options for using cellular data for all of these functions were reviewed, but proved cost-prohibitive. All Wi-Fi communications should be routed through the MGR regardless of whether the on-board device is directly integrated with the IVU/VLU or not.

ON-BOARD DEVICE	NOTES ON INTEGRATION INTO EMERGING ON-BOARD ARCHITECTURE
Automated Passenger Counters (APCs)	For rail vehicle APC sensors and analyzers could be integrated with the IVU/VLU as part of ATMS II. To maintain architecture consistency and avoid potential integration issues down the road, APC logic should be deployed on an open platform with an on-board operating system consistent with the IVU/VLU operating system.
Video Surveillance System (VSS) & Live Video Feeds	Currently Metro rail vehicles are deployed with a range of makes/models/ages of on-board surveillance systems. As part of the emerging architecture, all VSS on-board fleet vehicles should be Ethernet/IP capable and be connected to the on-board network and MGR. Newer DVRs that are part of the VSS have 2TB of storage to support Metro video retention requirements. Ultimately, once the Connected Fleet Vehicles and Facilities projects are complete and the DIMS and video storage efforts done, it may not be necessary to maintain such substantial storage on-board the vehicles. All video (with sound) downloads, uploads, and live feed access should be communicated through the MGR with the MGR providing QoS and prioritization functionality. Only some Metro VSS are capable of live video feeds, but this should become a standard requirement for all new and replacement systems, as it was viewed as a high priority need. ATMS II costs include some % of VSS replacements on the existing fleet to meet this standard. It is not intended that the architecture support full time live video feeds from a large number of vehicles, and live feeds would be focused on emergency or special situations with a selected group of operations, security, and law enforcement staff having the ability to activate live feeds.
Info Display	The on-board architecture can be integrated with the newer rail vehicle enhanced passenger information displays. This platform should be standardized over time and deployed common across all rail vehicles regardless of make/model/age. This is a major advantage of bringing the new architecture to rail vehicles, in that a wide variety of information and changes over time can be supported for customer information systems on-board.
Smart Drive	SmartDrive is currently an independent system on some Metro rail vehicles. Its primary focus is for incident surveillance and risk management where situations trigger video saving and download for basic on-board and outside front views. SmartDrive is highly valued by Metro for these functions and the ease of access the stored/tagged video. It will remain separate as part of the new on-board architecture for the foreseeable future.
Independent Rail Systems/Elements	In addition to the voice radio, the on-board architecture would not seek to integrate some very specialized and often line specific rail elements, including track wayside functions, ProTran rail worker safety alert, and train protection separation/systems. In fact, it is generally preferable to leave train safety/separation and track wayside components separate from the more broadly accessible elements of the on-board architecture supporting communications through the MGR.

3 Supporting Systems

> This section describes elements of the Strategic Plan technology program that support improved operations and customer experience today, and better prepare Metro for future technology solutions.

Supporting systems are those elements of the technology program that further support operational efficiencies and overall cost reduction through the implementation of common platforms and single-sources of information along with improved ease of use for Metro staff interacting with the systems. Supporting systems have been grouped by major technology area and include traveler information, SCADA, video, and yard management. Some of the recommended projects in these categories build upon the improvements achieved from the foundational elements, such as leveraging the improved data sources from the ATMS II implementation for traveler information or the ability to support real-time on-board video streaming through the improved data throughput achieved in the data communications projects.

3.1 Traveler Information Systems

Like passengers of all transit agencies, Metro passengers expect accurate and timely traveler information including trip planning, vehicle locations, arrival/departure predictions, and service alerts at all stages of their journey; through a variety of media including on the agency website, electronic signs in stations, and third-party apps and websites created by developers. Metro aims to meet these expectations and provide high-quality real-time passenger information for its passengers.

In the past decade, Metro has invested significantly in advanced traveler information systems for bus and rail, including successful efforts with enhanced trip planners, developer information portals, and customer information systems. However, a considerable number of work remains to improve the quality of the information provided to travelers and the consistency of information that is provided to bus and rail passengers.

Through interviews with agency staff, clear needs were identified related to the improvement of the quality of real-time location reporting and prediction information for bus and rail passengers, more consistency of the information provided to bus and rail passengers, improved incorporation of service adjustments/alerts into traveler information feeds, and consolidation of traveler information dissemination on electronic information signs.

The strategic plan recommends a set of projects categorized into the three overarching initiatives to help Metro meet these needs and greatly improve customer experience:

- Rail vehicle locations and arrival predictions
- Multi-modal systems, including service alerts
- Customer-facing systems

Note: improvements to vehicle locations and arrival predictions for bus are covered in the data communications and ATMS II project descriptions.

Rail Vehicle Locations and Arrival Predictions

The need to improve rail vehicle location information and arrival predictions was identified as critical to improve both operations and the customer experience. This need will be met by the implementation of a

series of separate phased projects described below. While Metro currently uses NextBus to make predictions for rail vehicle arrivals, the prediction engine used is the same as the engine used for bus arrival predictions. Using a bus arrival prediction engine for rail vehicles can result in accuracy issues as rail vehicles tend to behave differently from buses due to the nature of rail travel. For instance rail vehicles are unable to pass each other on a single track (or route) and trains must maintain longer, safer minimum following distances.

The recommended projects are necessary in order for Metro to operate a refreshed and more robust multi-modal alerts system that expands on the agency's existing real-time passenger information platform to provide the more accurate and timely rail vehicle location data and arrival predictions. The following recommended, sequenced projects offer best practice solutions with a risk-averse approach to future proofing.

GPS + Track Wayside Circuits (TWC) and Beacons for Rail Vehicle Locations

Project: T.4

This project deploys the additional devices necessary on rail vehicles, at platforms/stations, and along the track, as needed, to support improved rail vehicle location and arrival predictions. Roof mounted GPS units are to be installed on trains for the above ground tracking vehicle locations in real-time. The GPS data is augmented with existing and track circuits that will be added where possible and where wireless beacons are not possible. The combination of TWC and beacon data gives improved rail vehicle location information for arrivals and departures at stations, and GPS data gives improved rail vehicle location while between stations. While the current vehicle location systems largely meet operational needs, this additional level of vehicle location granularity is necessary to provide more accurate and timely rail arrival predictions for customer information platforms.

Example of Track Beacon Hardware

Benefits

- Improved vehicle location accuracy results in more accurate time of arrival predictions.
- More accurate time of arrival predictions will improve customer satisfaction with traveler information system.
- Minimized costs through leveraging of existing hardware with cost-effective hardware to fill gaps.

Technical Analysis Summary

The deployment of extensive additional track wayside circuits (TWC) will be costly, and the deployment of multiple location devices will result in separate maintenance and operation requirements. Through the use of a blend of rail vehicle location equipment, including existing TWCs and more cost-effective GPS and beacon hardware, Metro will see a simultaneous reduction in implementation costs and an increase in location accuracy across its rail lines.

Once this solution is implemented, the SCADA system will no longer be single provider for rail vehicle location information, unless the GPS and beacon info is brought into SCADA.

(Note that a cost-benefit analysis will still be necessary to determine where TWCs and beacons would best be deployed.)

Benchmarking

MBTA (Boston) uses a combination of track circuits, GPS, and TWCs on its Green Line light rail. RTD will use track circuits and TWCs, and is considering GPS in the future. No implementation of beacons in combination with other sources is known at this point.

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 2.8M	$ 940K

Additional cost break down information may be found in the ROM Section 5.

Capital and O&M costs could be reduced if GPS capability captured under Connected Vehicle or ATMS II deployments.

Assumptions

- ATMS II AVL features for rail will also be implemented to improve rail vehicle location reporting.
- Implementation of a cellular data network for rail.

Implementation Considerations

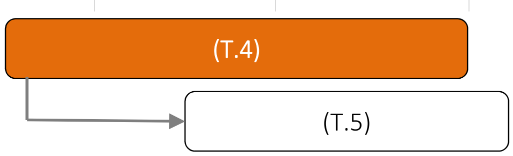
Implementation of a cellular data network for rail will need to be implemented earlier or in conjunction with this project.

Implementation Schedule and Key Dependencies

At the time of this plan, Metro plans to move forward with the Connected Vehicle project, which will include mounting of separate GPS units on rail vehicles. These GPS units are necessary for improving rail vehicle locations and arrival time predictions augmenting the track wayside circuits. Costs of these GPS devices are included in project T.4; however, cost for T.4 may ultimately be reduced if the Connected Rail project is completed or if the work is rolled into the ATMS II project (A.5+A.5i).

T.4 must be in progress, at a minimum, in order to move forward with the Rail-specific Prediction Engines project (T.5), which is covered in the next section.

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*



(T.4) GPS + Track Circuits and Beacons for Rail Vehicle Locations

(T.5) Rail-specific Prediction Engine

Rail-specific Prediction Engine
Project: T.5

Metro develops a stand-alone arrival prediction engine specifically for rail vehicles that expands Metro's rail prediction capability beyond what is currently available through NextBus. This prediction engine would be able to handle the specific rules and characteristics of rail vehicle travel. Potential features include:

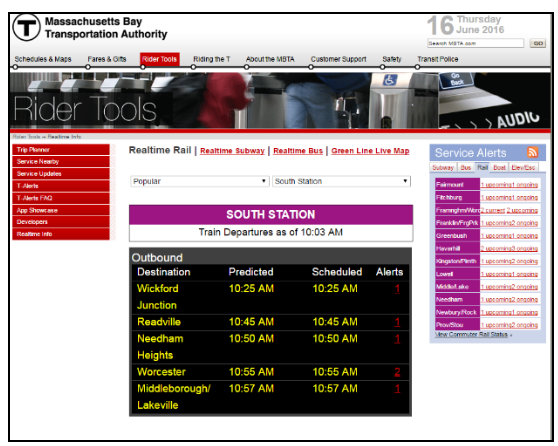
- Trains cannot pass each other.
- Trains have to maintain safe separation.
- Improved predictions when there are delays
- Account for short-turns, diversions, bus bridges
- Account for terminal operations/turnaround
- Account for unscheduled out of service trains
- Account for unscheduled extra service trains
- Account for trains operating on a different route/branch than scheduled
- Remove predictions for trains that move to an out-of-service location (yard, storage track, etc.)

Benefits

- Improved prediction accuracy improves passenger confidence in Metro system and improves passenger's travel experience.
- Provides Metro with additional rail arrival prediction capabilities; no longer limiting the agency only to NextBus availability, functionality, and features.

Technical Analysis Summary

This solution can be designed and developed so the core prediction engine system takes into account the operating realities and special cases of each Metro line. The custom software development will require integration with SCADA, ATMS II, and the hardware implemented during the Track Wayside Circuits and Beacons Project T.4, to incorporate improved vehicle location information. This will require some modifications to the existing SCADA software. This solution will minimize latency between prediction engine output and downstream users (e.g., website, traveler information signs, GTFS-realtime, API, etc.), and allow Metro to choose to pursue a solution that does not require ongoing Software as a Service (SaaS) costs.



Example of Real-time Passenger Information Available with a Rail-specific Prediction Engine

Benchmarking

Rail-specific prediction engines are currently implemented or planned at MBTA (Boston), CTA (Chicago), WMATA (Washington DC), RTD (Denver) and BART (San Francisco Bay Area).

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 562K	$ 536K

Additional cost break down information may be found in the ROM Section 5.

Assumptions

Data from all rail vehicle location technologies (TWCs, beacons, and GPS) would be utilized in the prediction algorithm.

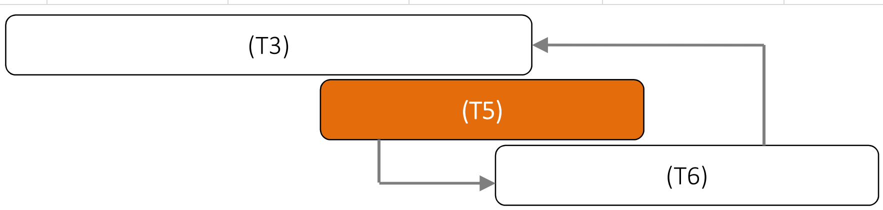
Implementation Considerations

Implementation Schedule and Key Dependencies

Building on Project T.4, this prediction engine would utilize the additional rail vehicle data provided by Project T.4 to improve real-time rail vehicle information disseminated directly to customers and customer service representatives.

Project T.5 must be in progress in order to complete the Multi-modal Alerts System project (T.3) because the alert system will ultimately pull data from this engine, as well as the enhanced data aggregation system (T.6) discussed below that will help improve Metro operations through the provision of better information to bus and rail controllers and customer service representatives.

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*



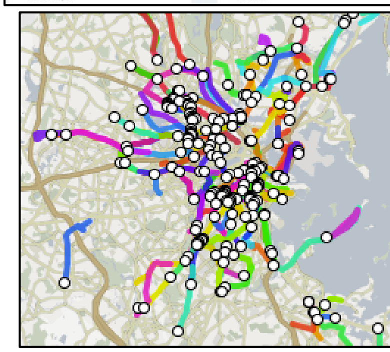
(T.3) Multi-modal Alerts

(T.5) Rail-specific Prediction Engine

(T.6) Enhanced Multi-modal Real-time Aggregation System + Single GTFS-realtime Feed

Multi-modal Systems and Service Alerts

A key challenge for accurate and consistent traveler information is maintaining data quality across systems. Whenever data is passed between systems and subject to different rules or identifiers, inconsistencies can arise. This is especially true where external systems such as NextBus, Google, and other third-party applications are gathering information from separate locations. Minimizing data sources and developing a single source for open Metro data is the recommended solution to reduce the opportunity for the dissemination of inconsistent data to the public. Furthermore, conveying information to customers during service changes and disruptions is a vital tool to improve the transit customer's travel experience. While Metro has made investments in RSS and Twitter feeds for sharing alerts information, Metro stakeholders identified the need for a unified alerts interface for bus and rail that is capable of sharing system information to customers during service changes and disruptions, e.g. detours, bus bridges, etc.



Improved Alerts Systems Help Ensure Accurate Information on Multiple Platforms

To best take advantage of national transit apps including Google Maps, RideScout and the talents of local developers, it is important to provide transit information to the public in standardized formats. While Metro provides schedule data through GTFS and arrival information through the NextBus API, a need was identified to provide data through the GTFS-realtime standard. GTFS-realtime leverages the existing GTFS schedule data by providing incremental updates where transit predictions are available. The consistency between the GTFS and GTFS-realtime datasets increases the utility and accuracy of websites and apps that use these data—directly improving customer information.

To directly address these needs, the following sequenced projects build on completed work to improve rail vehicle location and arrival prediction. They will help meet the core goal of providing better quality information to customers and thereby increasing their trust (and use) of Metro services.

Multi-modal Alerts System

Project: T.3

Metro implements a new system to enter, manage, and disseminate alerts with a focus on streamlining the alert creation process and disseminates the alerts via multiple channels. By implementing a more effective and accurate alert system, Metro would improve the accuracy and timeliness of its real-time passenger information systems; providing better information to customers, allowing them to make more informed travel decisions, and generally improving their experience with and confidence in Metro's services. This system would provide the platform through which alerts are entered into the real-time passenger information platform, and, as such, should be underway prior to other data aggregation and improvement projects.

Benefits

- More effective alert system allows passengers to make more informed decisions and improves the passenger's transit experience.
- Potential costs savings through a single system solution through reductions in staffing and ongoing software system maintenance costs.
- Single source for traveler information alerts simplifies system interfaces

Technical Analysis Summary

This solution allows for system-wide (bus and rail) alerts to be created in a single location, along with one system for external systems and apps to retrieve alerts information. A single system reduces total operation and maintenance requirements in part by reducing the number of staff required to operate the system. This will require internal coordination to maintain user privileges to allow appropriate access for staff.

This solution can be implemented separately from ATMS II if Metro would like to move forward more quickly with the traveler information systems program described in this plan, or there is an option to roll this into the ATMS II implementation providing the selected vendor brings the capabilities and system features and functions necessary. However, CAD/AVL vendors may be unable to provide an integrated bus and rail alerts system. Currently, many CAD/AVL vendors provide only basic alerts functionality. Additionally, Metro may not wish to have its traveler information systems program constrained by the ATMS II implementation (e.g., schedule, duration, features and functions trade-offs, etc.).

Benchmarking

A combined bus and rail alerts system is currently operational at MBTA (Boston), and CTA (Chicago); it is being planned at WMATA (Washington DC); and is being implemented as a pilot at Metro.

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 636K	$ 1.0M

Additional cost break down information may be found in the ROM Section 5.

Assumptions

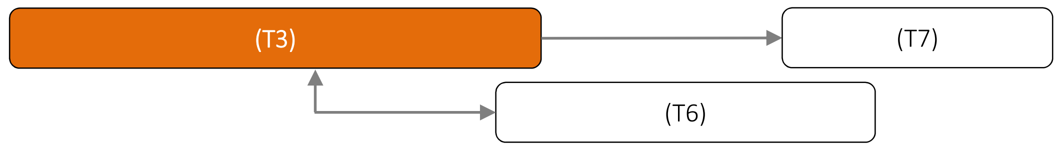
- Costs assumed separate/new could-based service.

Implementation Considerations

Implementation Schedule and Key Dependencies

This is one of the first projects recommended in the sequenced traveler information systems program. Once the enhanced multi-modal real-time aggregation system and single GTFS-realtime feed project described in the following project description is underway, it will begin to provide improved, consistent data to the alerts system, which will, in turn, provide accurate, real-time, multi-modal alerts to the recommended real-time passenger information (RTPI) portal on the Metro website, as well as the other Metro customer information systems.

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
2016	2017	2018	2019	2020	2021	2022	2023



(T.3) Multi-modal Alerts

(T.6) Enhanced Multi-modal Real-time Aggregation System + Single GTFS-realtime Feed

(T.7) Webpages with RTPI

Enhanced Multi-modal Real-time Aggregation System + Single GTFS-realtime Feed

Project: T.6

Metro builds upon the existing agency open data and API systems (i.e., developer.metro.net) to aggregate information from ATMS II, SCADA, the alerts system, and, possibly, from NextBus (for bus predictions) to provide a single-source of traveler information including vehicle locations, arrival predictions, and alerts along with the implementation of a new, single, GTFS-realtime feed providing improved accuracy on customer-facing portals like the agency website and mobile app.

Benefits

- Improved traveler information system with alerts allows passengers to make more informed decisions and improves the customer transit experience.
- Improved GTFS-realtime feed results in better accuracy of location information provided to passengers and improves the customer transit experience.
- Provides a unique opportunity to use the aggregated data to feed downstream Metro systems such as traveler information webpages and apps.

Technical Analysis Summary

This provides a flexible solution to meet Metro's customer needs for schedule, prediction, and service alerts info for rail and bus in a single, cohesive system. APIs and standardized feeds allow the dissemination of current, accurate schedule, prediction, and service alert information to third-party apps and websites through a single source, ensuring GTFS-realtime data is consistent with schedule data from bus and rail information systems. This allows developers to leverage existing apps or create new apps to meet Metro customer needs (e.g., ADA requirements). This will require access to API service be controlled and monitored. As well, changes to the GTFS-realtime feed, such as additional fields for data entry, may be more easily implemented. To achieve the benefits envisioned from this solution, the system must be integrated with both the bus and the rail schedule systems. Finally, consolidation of systems may reduce overall operations effort and IT support. However, this may be offset as an internal system requires additional effort for system operation, maintenance, and monitoring.

Benchmarking

MBTA (Boston), BART (San Francisco Bay Area), TriMet (Portland) have had success developing aggregation systems. These systems form the foundation for their traveler information systems, and improve the agencies' abilities to share consistent and accurate information.

Many agencies that offer both rail and bus services have implemented or are planning to implement a single multi-modal GTFS-realtime feed including MBTA (Boston) and TriMet (Portland)

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 1.9M	$ 1.2M

Additional cost break down information may be found in the ROM Section 5.

Assumptions

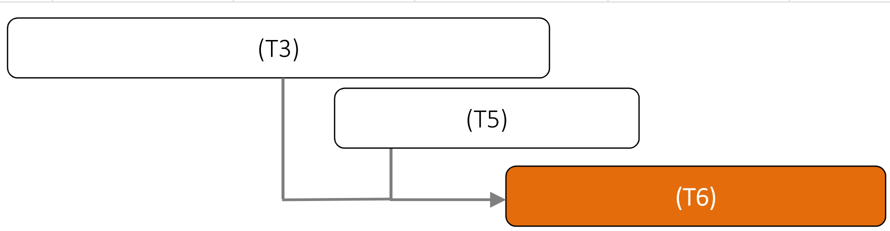
- The design, implementation, and testing of traveler information systems including, schedule, prediction, and alert information is directly available to the public and to third parties through APIs
- The bus and rail systems have prediction functionality

Implementation Considerations

Implementation Schedule and Key Dependencies

This solution depends on the Multi-modal Alerts System (T.3) to be implemented and the Rail Prediction Engine (T.5) to be underway first. As part of the overall recommended traveler information program, it is anticipated this project would utilize the improved rail prediction engine data from project T.5 and would provide the harmonized data necessary to gain the best utility from project T.3.

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*



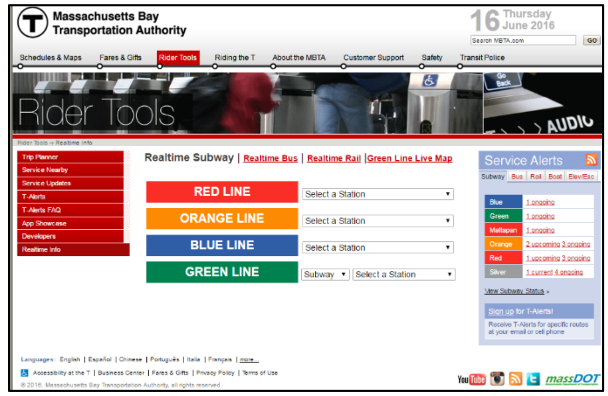
(T.3) Multi-modal Alerts

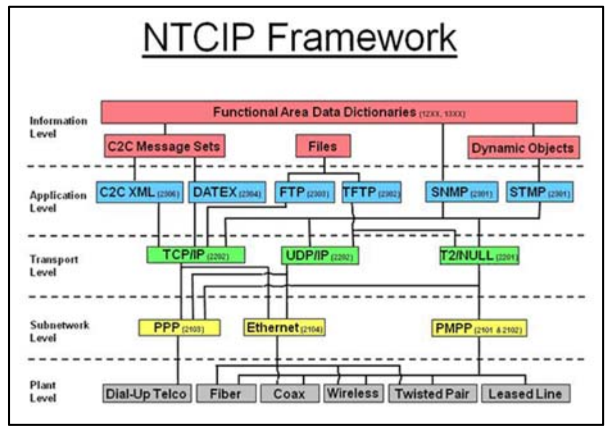
(T.5) Rail-specific Prediction Engine

(T.6) Enhanced Multi-modal Real-time Aggregation System + Single GTFS-realtime Feed

Customer-facing Systems

Metro currently relies on NextBus modules that are embedded in the Metro website to relay schedule and arrival information to customers. However, customers are increasingly relying more on smartphones and mobile devices to access transit information. Web pages and apps that are able to leverage those devices' functionality, e.g., GPS locations improve the customer experience. While Metro has made a considerable investment in customer information through NextBus, using the NextBus tools available can be confusing due to the large number of options available to users. By unifying the web pages available into an easier to navigate traveler information website and mobile app, Metro would significantly improve the customer experience.





Standardized and Improved Data along with Standardized Customer-facing Information Tools Improves Customer Experience System-wide

Rail and bus passenger information signs at stations and stops are also currently driven by a wide variety of systems with different capabilities and standards. The different systems require Metro staff to enter information in multiple locations and maintain knowledge of several operating systems. The numerous types of signs in use require maintenance staff to maintain replacement inventories for several different sign types and retain the knowledge to repair them. These inefficiencies result in extra costs and the possibility of incorrect information being presented to customers. Thus, Metro has expressed a need to unify the Transportation Passenger Information System under a common platform that reduces efforts to disseminate information via the signs and streamlines maintenance.

The following recommended projects also are envisioned to build upon the improvements described in the sequenced projects above.

Webpages with RTPI
Project: T.7

Metro redesigns the Metro bus and rail arrivals web pages to present real-time information including: schedule, predictions, vehicle locations and service alert information. Specifically, the redesigned pages will allow users to access real-time information for their specific route, direction, trip, stop, or any combination thereof. This option could be integrated with either the NextBus API or the Bus and Rail Traveler Information System (TIS) API.

Benefits

- Improved traveler information system with alerts allows passengers to make more informed decisions and improves the passengers' transit experience.

Technical Analysis Summary

This solution releases Metro from the limitations of the NextBus design and functionality, and provides the opportunity to implement a webpage that is responsive specifically to Metro and its customers' need for real-time passenger information. These new and responsive webpages can be optimized for desktop and mobile device use, providing a consistent experience for customers across all platforms.

This solution would either be limited to internal implementation resources or external developers. It is recommended that Metro contract with a vendor for the design and roll-out of the new webpage. The webpages could be provided as part of the ATMS II project implementation, as long as the ATMS II vendor possesses the technical capabilities to develop the webpages and their cost is not prohibitive.

Benchmarking

Many agencies have implemented or are planning to implement web pages with RTPI including TriMet (Portland), CTA (Chicago), MTC (New York City), and MBTA (Boston), RTD (Denver).

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 381K	$ 433K

Additional cost break down information may be found in the ROM Section 5.

Assumptions

- The Metro website has access to APIs with RTPI information
- Hosting would be provided by existing hosting service

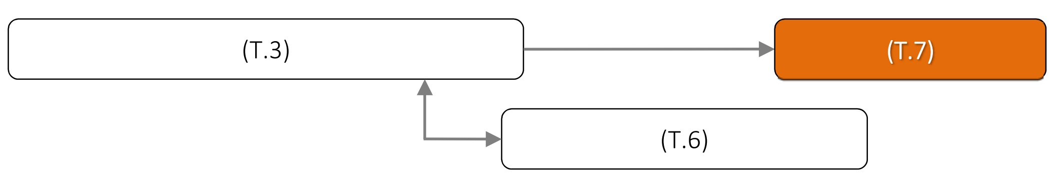
Implementation Considerations

Ideally, the web pages would be driven by an aggregation system as recommended in project T6 with the data provided via a single source alerts system as recommended in project T3. It should also be responsive to desktop computers (including laptops) or mobile devices (including tablets and smartphones), changing information displays and options based on characteristics of the device, e.g. screen size, GPS ability, and so forth.

Implementation Schedule and Key Dependencies

The Multi-modal Service Alerts system (T.3) needs to be implemented first to provide the alert information to be consumed by the webpages.

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*



(T.3) Multi-modal Alerts

(T.6) Enhanced Multi-modal Real-time Aggregation System + Single GTFS-realtime Feed

(T.7) Webpages with RTPI

NTCIP-compliant Station Signs with Common Sign Control

Project: T.8

Metro replaces existing non-compliant signs with National Transportation Communications for ITS Protocol (NTCIP)-compliant signs at bus stops, rail stations, and transit centers. Metro would also implement a common sign control system with an accessible API for controlling sign information. This reduces the number of systems required to maintain and operate, translating into direct operating cost reductions for Metro for the labor required to manage and maintain the signs and the spare parts necessary to have on hand. A common sign control system would also reduce the opportunity for incorrect or different information to be entered into any particular sign sub-system, ensuring more consistent information is disseminated across the customer information platform.

Benefits

- Reduced number of TPIS sign systems to maintain and operate.
- Reduced labor required to manage and maintain signs.
- Reduced incorrect or disparate information displayed at a given platform.

Technical Analysis Summary

A single sign control system for control of all Metro signs would reduce operations and maintenance requirements and free Metro from the limitations of NextBus support, features, and functionality. In addition, NTCIP-standardized interfaces allow for compatibility with other sign control systems. Utilization of APIs allows additional systems to have access to control the signs, e.g. an alerts system, allowing the NTCIP-compliant signs to be used by other passenger information systems. The public sign control system API could also be made available for developers to create apps to meet ADA requirements.

Benchmarking

NFTA (Buffalo) relies on NTCIP signs for the presentation of information at its stations. MBTA has integrated its signs with a traveler information aggregation system for consistent data.

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 6.8M	$ 4.4M

Additional cost break down information may be found in the ROM Section 5.

Assumptions

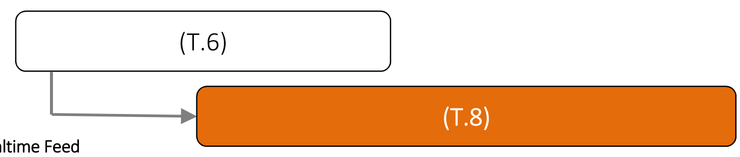
- All signs are controllable through NTCIP standard

Implementation Considerations

It is anticipated the standardized signs would be integrated to pull data from the enhanced aggregation system implemented under project T.6 along with the Multi-modal Alerts System (T.3).

Implementation Schedule and Key Dependencies

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*



(T.6) Enhanced Multi-modal Real-time Aggregation System + Single GTFS-realtime Feed

(T.8) NTCIP-compliant Station Signs with Common Sign Control

Rail Station Public Address System Upgrade and Integration
Project: T.9

Metro upgrades the public address (PA) systems to provide one consistent system across all rail stations, either through identification of a new system or utilizing an existing PA system and upgrading the PA systems at all stations to be compatible with the chosen system. The main considerations for Metro in meeting its PA needs are performance, reliability and cost. A single, unified system would increase the reliability of the PA system by removing redundant, and potentially error-prone procedures with the use of multiple systems. The increased capital costs to implement the new system would be offset by decreased operations and maintenance costs. A unified PA system also would improve the customers' transit experience by providing consistent information throughout Metro's transit system.

Benefits

- Improved reliability of the PA system
- Improved customer transit experience by providing consistent traveler information throughout all modes and platforms

Technical Analysis Summary

This solution creates a single, unified PA system that eliminates duplicate systems and reduces efforts to maintain disparate systems. A unified PA would require integration with existing PA system equipment at the stations and platforms. The PA system could be integrated with the existing Traveler Information System (TIS) to satisfy ADA requirements.

Benchmarking

While many agencies currently operate separate PA systems, many are considering consolidating them into single systems. MBTA (Boston) has had success in reducing operations efforts and costs by implementing a system-wide PA system for rail operations.

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 2.0M	$ 2.0M

Additional cost break down information may be found in the ROM Section 5.

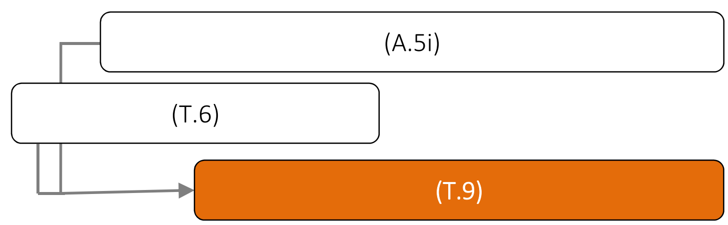
Implementation Considerations

There may be some cost reduction for the traveler information program if this project implemented at part of the ATMS II Rail project A.5i.

Implementation Schedule and Key Dependencies

Projects ATMS II Rail Implementation A.5i, and Enhanced Aggregation T.6 should be underway first, as the PA system would pull data from both newly implemented systems.

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*



(A.5i) ATMS II for Rail

(T.6) Enhanced Multi-modal Real-time Aggregation System + Single GTFS-realtime Feed

(T.9) Rail Public Address System Upgrade

3.2 Video Streaming for Bus and Rail

Rail and bus operations, as well as security groups, have expressed a need for the ability for live look-in for vehicles in emergency and other situations. Current international conditions and security threats will continue to push for the ability to view live on-board video. Bus controllers noted that a live look-in feature would allow for some process changes in responding to false emergency alarms on buses (i.e., a very high percentage of alarms were reported as false and are stretching law enforcement resources to

clear the alarms). Bus operations has also expressed a need to improve the safety of the bus operators, and rail operations staff have expressed a need for improved access to on-board video.

Example of Real-time On-board Vehicle Video Streaming for Bus

For the Task 3 alternatives analysis, Task 4 SWOT analysis, and Task 5 Cost Benefit Analysis, it was assumed that Metro has implemented a wireless data communication system for both bus and rail operations that has sufficient bandwidth to support streaming video. The differentiators between the alternatives were primarily the costs, future proofing, and which alternative would best meet Metro's needs. The highest scored alternative is E.V1 which reflects that providing real-time access to vehicle video when it is most needed at a much lower cost than the other alternatives is preferred.

The following paragraphs provide details of the recommended video streaming project.

Video Streaming for Bus and Rail
Projects: V.3 + V.4

This project involves enabling the streaming of the on-board video to the BOC and ROC during emergency situations. This project assumes each vehicle has an MGR with a cellular data connection that enables it to stream on-board video only during emergency situations. Metro has a pooled data plan for the entire fleet that is sufficient to enable a few vehicles to stream video during emergency situations. The video will be temporarily cached (but not stored) in the cloud, from where it can be streamed to viewers during an emergency.

Benefits

- The ability to view on-board video on demand during an emergency, which would improve the security of both the operator and passengers.
- There would be reduction in the need for the involvement of the Sheriff when there is a false alarm.

Technical Analysis Summary

This project provides cost effective real-time access to on-board video when it is needed most—during emergencies. Video is retained on board so historical video will need to be manually retrieved from the on-board digital video recorder (DVR). In the event of a severe incident, the equipment may be damaged and lose all stored data. Streaming server's transition between on/off states may generate errors and comes with latency. Privacy issues may arise if there is a security breach of live video.

Benchmarking

The Los Angeles Department of Transportation (LADOT) is upgrading its onboard hardware to enable real-time video streaming over a cellular network from vehicles on an as needed basis.

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 6.1M	$ 3.0M

Additional cost break down information may be found in the ROM Section 5.

Assumptions

- It is assumed Metro has implemented a cellular data network for data communications for the bus and rail fleets.
- Video streaming increases the monthly cellular subscription (approximately $5 per vehicle) for a pooled cellular data plan
- Video from vehicles in an emergency state is cached temporarily in the cloud but is stored on-board.

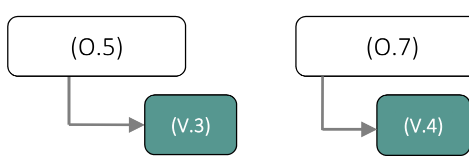
Implementation Considerations

Implementation of a high speed wireless data network should be implemented first or in conjunction. The ability to view streaming video from vehicles has only become feasible recently when 4G LTE cellular data service became readily available. Several agencies including LADOT are now planning to implement the viewing of real-time onboard video on an emergency basis now that the price for this service has dropped dramatically. Obtaining cellular data service to support continuous streaming of video from the vehicles may not be feasible today but could be in the future when 5G service becomes available.

Implementation Schedule and Key Dependencies

The figure below shows the time line for the implementation of the video streaming for bus and rail projects, and its dependency on the implementation of cellular data networks for the bus and rail fleets.

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*



(O.5) Fleetwide MGR (and cellular data) for Bus

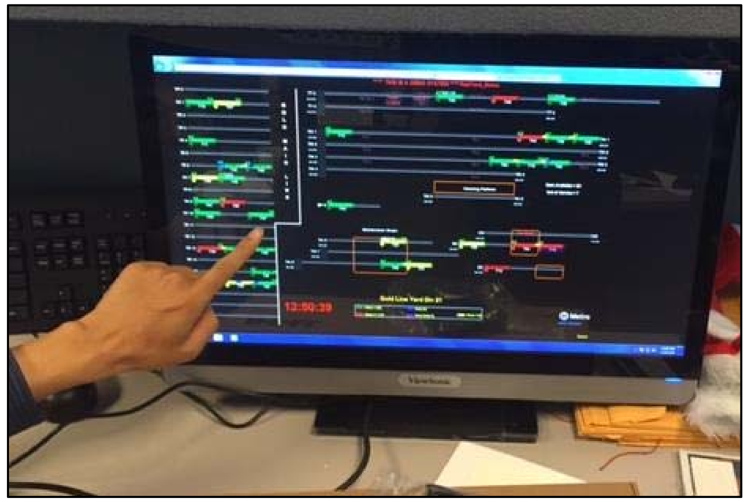
(V.3) Video Streaming for Bus

(O.7) Fleetwide MGR (and cellular data) for Rail

(V.4) Video Streaming for Rail

3.3 Yard Management Tools

Metro bus and rail stakeholders indicated extensive needs to support vehicle management, status tracking, and maintenance support functions in the yards. Metro attempted to deploy a yard management module early in the operational life of the current ATMS, but the vehicle location accuracy was not sufficient. Rail stakeholders indicated the need for enhanced yard management tools that could address the specific configuration of each of the rail yards, as well as assist with tracking status and providing integration to M3 and related vehicle maintenance/yard spotter functionality.



This is an example test display screen from the Metro-developed yard management tool pilot project (*rail yard shown*)

Comprehensive yard management tools support the following general functions:

- Automatic vehicle location tracking/placement, including identifying individual bus lanes /spaces and storage/primary track positions for rail vehicles
- Support for vehicle assignments and dispatching for scheduled (e.g. from HASTUS) and unscheduled situations (e.g. regular service or service emergency response) given vehicle status and positions in the yard
- Map views of the yard including placement of vehicles as available or unavailable for service in addition to status and location
- Ties to vehicle maintenance systems to indicate status and condition (open work orders, critical items, etc.)
- Operator vehicle location support (find my bus or rail vehicle based on operator ID or work assignment)
- Yard spotter and vehicle inspection integration (optional)

Metro has undertaken some in-house development efforts to provide a basic yard vehicle management and vehicle tracking tool. A pilot project was completed for the Blue Line rail yard but the tool will ultimately be expanded for use at the other rail and bus yards. The in-house tool provides a substantial level of functionality and information even in its pilot program form.

Example of Modern Yard Management Tool User Interface

This tool relies largely on manual input of vehicle location and status information into the system, similar to the magnetic or block displays often used for yard management, but it has the advantage of being available on-line to a wider variety of users at workstations. While mobile access to this tool has been considered, some stakeholder have voiced concerns about ensuring safety for personnel working in the

yard amongst the vehicle storage and movement areas. The development platform of the tool means that future data integration efforts could be supported and/or yard management functionality enhanced over time. Initial responses to the demonstration use of the tool by Metro have been positive and have led to development efforts to cover remaining rail and bus yards.

Prepare for and Implement Independent Bus + Rail Yard Management System

Projects: Y.4 + Y.5

This effort builds on current Metro efforts to support basic vehicle/yard tracking and status for bus and rail, but would not necessarily provide automatic assignments of vehicles to service blocks. Integration to the TDB and M3 would be included over time. This alternative can be viewed as combining the highest priority functions of D.M1 or D.M2 with the in-house development efforts of Metro. This alternative would take longer to implement as it would be phased over time.

Benefits

- Yard management tools would reduce the amount of manual labor performed by maintenance and operations staff.

Technical Analysis Summary

The in-house tool developed by Metro appears highly functional and successful. CAD/AVL system provided yard management tools have proven to be relatively high risk and are sometimes unable to meet the agency specific needs and the idiosyncrasies of yard configurations and vehicle placement. While a contracted fully custom or separate efforts offers promise, the costs would be substantially higher.

Improvements to on-board architectures and yard and mobile data communications are expected to radically transform the data communications and vehicle information available at the yards. As newer vehicles come on-line and offer enhanced vehicle health and status information automatically, this will dramatically impact and hopefully improve what can be achieved with yard management tools. In short, this is an area where the recommendation is for Metro to continue in-house development efforts, consider easy integration and functionality enhancements and bide its time until rail and bus fleet turn over makes a more comprehensive yard management tool easier, more functional, and less costly to implement. However, many of the manual functions currently performed to collect rail vehicle data could be simplified, semi-automated, and integrated with the in-house tools to continue to address priority needs in this area.

Benchmarking

SAP (http://go.sap.com/solution.html) custom solutions have been deployed for Canadian Railways; Trapeze Enterprise solutions for the Chicago Transit Authority (CTA).

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$11.6M	$5.7M

Additional cost break down information may be found in the ROM Section 5.

Assumptions

- New on-board architecture and connected vehicles in place for bus and rail.
- Yard Wi-Fi coverage in place for bus and rail.
- Continued development of Metro in-house yard tracking applications.

Implementation Considerations

The In-house yard tracking system should allow for near-term and future integration with M3 (or replacement) as well as enhanced yard management systems for bus and rail.

Implementation Schedule and Key Dependencies

The figure below shows the time line for the preparation and implementation of the Yard Management System. There are no critical dependencies to other projects.

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*
					(Y.4)	(Y.5)	

(Y.4) Prepare for Independent Bus + Rail Yard Management System

(Y.5) Implement Independent Bus + Rail Yard Management System

3.4 SCADA

SCADA provides monitoring and control functions for the controllers at the ROC. The SCADA human-machine interface (HMI) computers at the ROC provide the monitoring, alarm and control functions through a graphic interface. A cable transmission system (CTS) provides the communication link from the SCADA HMI to the SCADA remote terminal units (RTUs), which directly interface to the equipment in the field. Different SCADA HMI vendor platforms are currently in operation at the ROC, but Metro is currently in the process of moving all rail lines to the ARINC Advanced Information Management (AIM®) system.

The Task 1 Needs Assessment identified a significant need to make SCADA data available to other users besides the ROC controllers, especially maintenance and security staff. Controllers at the ROC who use the SCADA HMI are primarily responsible for train movements, but the nature of the SCADA architecture also requires them to supervise and manage wayside systems unrelated to train movements. The additional responsibility of the wayside systems is a distraction from the higher priority of ensuring safe train movements. Maintenance and security staff who are primarily responsible for the wayside systems have limited direct access to SCADA information.

Generally, SCADA provides monitoring, alarms, and control of equipment for the following systems: traction power, train control, electrical, mechanical, tunnel ventilation, communications systems, fire detection, security, and other miscellaneous systems. SCADA generates important alerts and information for rail operations and maintenance. This data is not always easily accessed outside of the SCADA systems. In addition, the alerts are not always directed specifically to the parties that need them, and are broadcast to a wide set of users.

Two projects were identified to address the identified needs for SCADA.

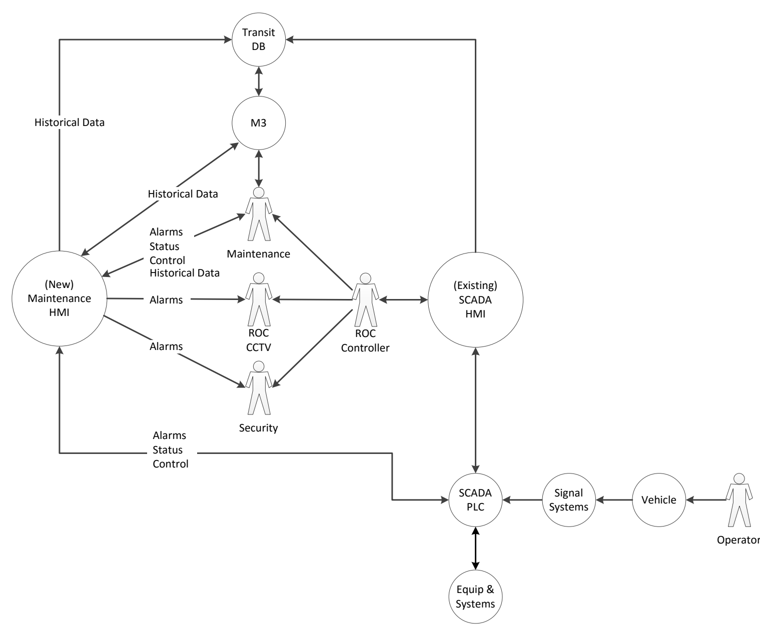
SCADA HMI for Maintenance Staff

Project: S.4

This project adds a SCADA interface for use by staff other than the ROC operators such as maintenance and security. This new SCADA interface would be constructed as an extension of the existing ARINC system with new workstations and new graphics. The new graphic displays would be optimized for maintenance functions and would limit control capability to prevent accidental interference with ROC controllers. The new graphics would include alarms for maintenance and security. The existing SCADA HMI for the ROC controllers would then be reduced or its functions simplified due to the functions that have been assumed by the Maintenance SCADA. Essentially, this project is a division of SCADA functions into a Maintenance SCADA and Rail Operations SCADA.

Benefits

- The primary benefit is freeing the ROC controller from being an information conduit for maintenance and security staff. This will improve the efficiency and effectiveness for ROC controllers who can focus on train movements.
- Maintenance staff will benefit with an interface that is tuned to their needs. There will be improved efficiency and effectiveness of the maintenance staff due to their improved access to system status and alarms.
- Security CCTV staff will benefit with improved alarm displays for security related points in the SCADA system.



Technical Analysis Summary

This project addresses the identified need for improved management of alarms and better relevance of the alarm information presented directly person who can respond. This project also addresses another identified need: the ability to send rail system intrusion alarms directly to security staff.

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 683K	$ 105K

Additional cost break down information may be found in the ROM Section 5.

Assumptions

- The ARINC SCADA software will be re-used.
- Metro's licensing agreement with ARINC includes unlimited SCADA clients.
- Development costs of new graphics will depend on the utility of the existing graphics for maintenance needs and security purposes.
- Most of the ROM costs are for graphics development.
- New client workstations and expansion of the SCADA network to maintenance staff locations are needed.

Implementation Considerations

Metro is in the process of moving all rail SCADA system to the ARINC platform. While it would be possible to begin the conceptual pre-design stages of this project at any time, it will be probably be more efficient to commence the actual development after the SCADA migration of all rail alignments is completed.

Implementation Schedule and Key Dependencies

The figure below shows the time line for the development of the SCADA HMI for Maintenance interface.

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*
	(S.4)						

(S.4) SCADA HMI for Maintenance Staff

SCADA Message Gateway

Project: S.5

This project implements a message gateway with an interface to SCADA to automatically send email, text or phone messages as triggered by alarms or events in SCADA. The person who receives the alarm responds with an alarm acknowledgement. The acknowledgement is received and logged by the SCADA system.

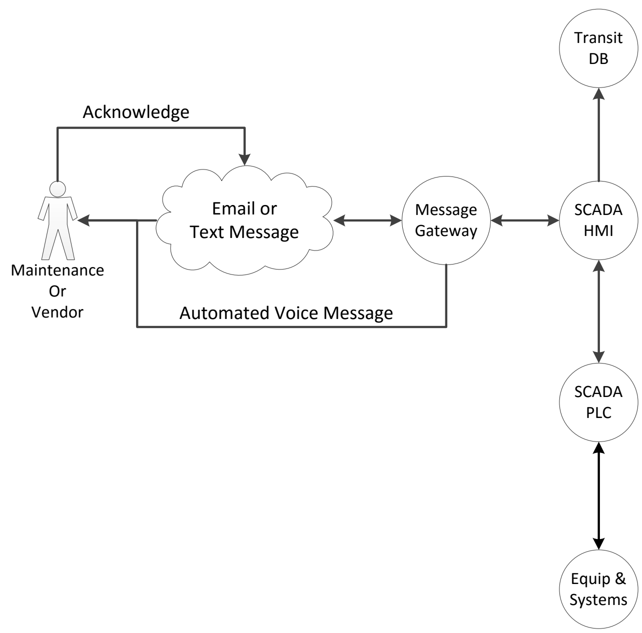
An example use case for an alarm sent and acknowledged via text message is as follows:

1. An equipment problem is detected by SCADA PLC.
2. The SCADA PLC sends an alarm to the SCADA HMI (the ARINC system).
3. The SCADA HMI sends an alarm to Message Gateway.
4. The Message Gateway sends an SMS text to the responder (Metro maintenance staff or contractor).
5. The responder acknowledges the alarm via text message.
6. Message Gateway sends the alarm acknowledgement to SCADA HMI.
7. The SCADA system logs the alarm activity including the acknowledgement.

Implementation of this gateway can be accomplished with off-the-shelf alarm notification products that can be integrated with the SCADA HMI (ARINC). Alternatively, the ARINC SCADA platform has been developed with at least a beta version of this capability.

Benefits

- A significant advantage is the reduction of work load for the ROC controllers who maintain awareness of equipment readiness but no longer need to contact maintenance responders.
- The acknowledgment aspect of this upgrade provides a simple level of response coordination. If a potential responder receives the alarm but is unable to respond, they can decline to respond. The system will then message the next person on the responder list.
- This upgrade is compatible with a business model where Metro contracts with outside vendors for certain maintenance areas. A system or equipment under warranty can have alarms configured to activate an outside maintenance vendor directly.
- SCADA logging of the alarm-related activity provides a basis for evaluation of a maintenance vendor's responsiveness.



Technical Analysis Summary

This project addresses the identified need for improved ability of the SCADA system to automatically generate data and forward it to the relevant personnel. An automated messaging function frees the ROC controllers from performing this routine task. This will allow the controllers to focus on higher priority activities such as managing train movements.

Cost Summary

CAPITAL COSTS	O&M COSTS (10yr)
$ 397K	$ 12K

Additional cost break down information may be found in the ROM Section 5.

Assumptions

- Off-the-shelf hardware and shrink-wrapped software costs are small compared to the labor necessary for integrating with SCADA and for configuring the alarm notifications.
- Costs include the design phase and project management costs during construction.

Implementation Considerations

Implementation of the gateway will require the direct involvement of Metro maintenance staff to appropriately configure the notifications. There are a number of different ways to send messages including phone call, SMS text and email. Texting is probably the most preferable for most people.

However, this could mean that Metro is obliged to provide smartphones or reimburse employees for use of their personal smartphones.

Implementation Schedule and Key Dependencies

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*
2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*
		(S.5)					

(S.5) SCADA Message Gateway

4 Strategic Plan Timeline and Relationships between Fleet Systems

This section provides an overall Strategic Plan timeline highlighting key dependencies between current, planned, and recommended projects, along with diagrams illustrating impacts to current and planned system interfaces as a result of the recommended projects.

4.1 Overview

This Strategic Plan describes a series of on-going, recommended, and supporting fleet communications and technologies projects that seek to fulfill the needs outlined by Metro at the outset of the planning effort. Any Plan is subject to funding and policy realities and priorities that impact details of the projects implemented, timing, and the relative sequencing of projects. This section of the Plan provides a big picture overview of the recommended, existing and planned projects outlined in a timeline format.

This Plan is intended to be "living document" where timelines and cost estimates can be updated over time to reflect Metro's changing priorities and on-going development efforts. The timeline in this section collectively lists projects with anticipated timeframes out to 2025. Planned projects beyond that timeframe tend to fall into on-going project monitoring, maintenance, and configuration management. The ROM cost estimates provided in the following section reflect current 2016 estimates using current US dollars. This Plan provides sufficient detail to allow the projects to be implemented separately or aggregated as Metro's needs may dictate.

4.2 Relationships between Fleet Systems Projects and Timing

Figure 3 displays the overall Strategic plan and timeline for the recommended projects and supporting projects. Key dependencies are noted as arrows between projects, and each project is identified with a title and ID code that references back to the individual project descriptions. The timeline lists three basic categories of projects:

- Foundational – Foundation project recommendations are core elements and efforts that are required to make effective progress and enable the use of all the remaining project functionality described in the Build-On and Independent categories. This category contains the basic voice and data communications project required to support fleet systems upgrades and replacements. It also contains the ATMS II project that replaces the aging current ATMS and significantly enhances it to include new functionality, improved operational interoperability, and rail support functions. Finally, this category includes incorporation of a new on-board systems architecture that started with Metro's existing Connected Fleet Vehicles & Facilities project and is incorporated into all the other remaining project recommendations. Without the foundational projects in place, Metro will find it much more difficult to implement and make full use of the broader set of fleet systems and supporting traveler information functions described in this Plan.
- Supporting – Supporting category projects seek to leverage the foundational efforts, particularly the communications and elements of ATMS II to provide more robust and capable fleet management solutions. Metro is already undertaking some efforts in this area with the DIMs project for video requests/management as one example. The full implementation and success of these efforts will ultimately hinge on the foundational elements. Some of these traveler information projects and related SCADA upgrades can be undertaken without direct integration with the foundational project, but the success of most of the efforts will be leveraged upon elements of ATMS II, communications improvements, and the implementation of a more open and flexible on-board architecture.

- Visionary – Visionary projects Include both Connected Vehicle (CV) and autonomous vehicle concepts. The identified items are not intended to represent recommended projects with associated costs. Instead they are estimated timeline triggers for Metro's consideration in moving forward with autonomous and connected vehicle applications for transit. As discussed in the specific Connected and Autonomous vehicle section of this Plan, communications and fleet systems have a pivotal role to play in the on-going roll out and operationalization of CV functions and projects. These elements are listed for reference purposes for Metro's on-going planning and preparation for CV and autonomous vehicle efforts.

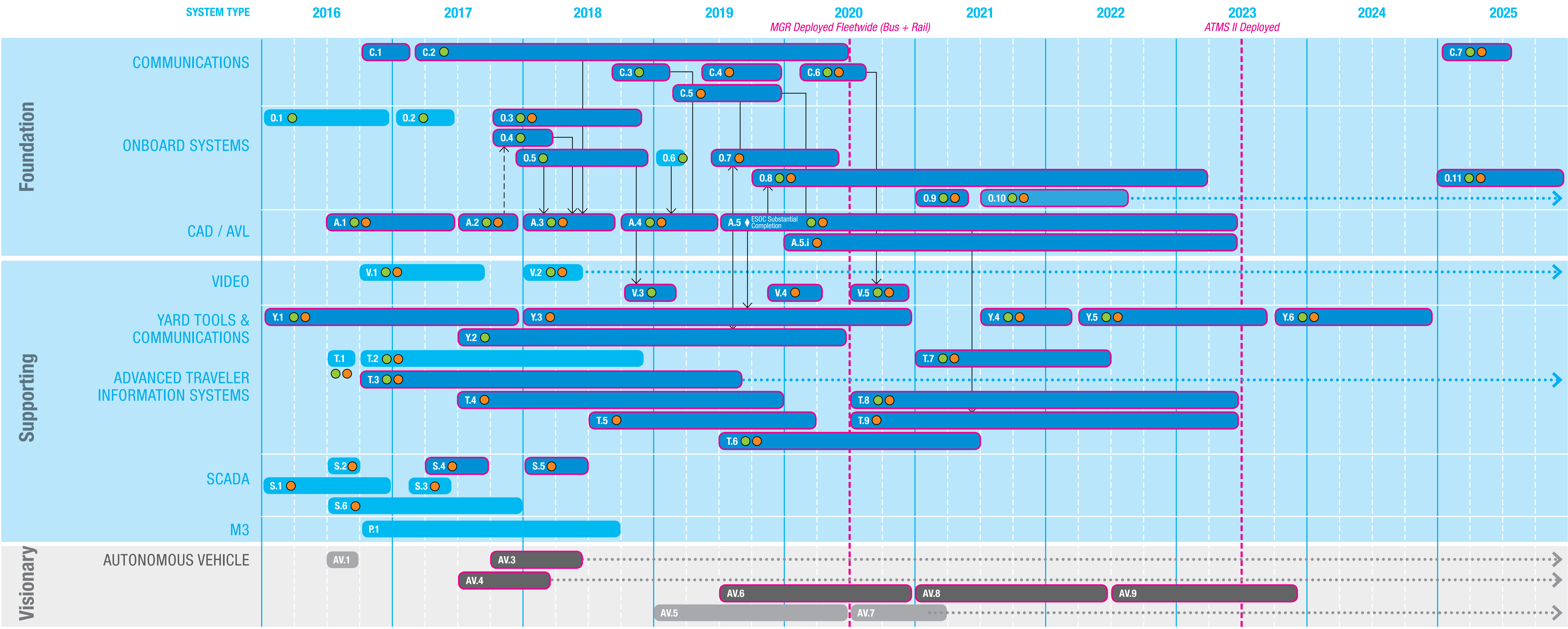
For each project listed in the timeline:

- Recommended projects described in detail in the plan are highlighted,
- Color dots represent bus (green), rail (orange), or both.
- Abbreviated names are noted in the reference legend under the timeline.

In addition, other key anticipated timeframes are noted such as the anticipated completion of Mobile Gateway Router (MGR) fleet-wide deployment and the anticipated ESOC operations center readiness for fleet systems transition/integration. A separate effort by Metro is noted for the upgrade and replacement of M3, the maintenance management application platform that receives and provides data to a number of other fleet systems.

Figure 4 provides another view of the relationship between the recommended projects and all known planned and current ongoing projects at the time of this Plan. A brief description for each of these projects may be found in Appendix B.

Figure 3: Strategic Plan Technology Program Project Timelines and Dependencies



BUS

RAIL

COMMUNICATIONS

- C.1 Drive Test (cell + LA-RICS)
- C.2 Connected Vehicle: Establish (Commercial) Cellular Data Service for Bus Fleet
- C.5 Connected Vehicle: Establish (Commercial) Cellular Data Service for Rail Fleet
- C.3 Establish VoIP for Bus Fleet (w/ radio backup)
- C.4 Implement LA-RICS LMR in Tunnels for Sheriff
- C.6 Assess 5G Service + LA-RICS LMR for Bus and Rail Fleet and Update Comm. Plan
- C.7 Assess 6G Service and First Net for Bus and Rail Fleet and Update Comm. Plan

ONBOARD SYSTEMS

- 0.1 Router Pilot Project
- 0.2 Expand Router to 500 Vehicles (Connected Bus)
- 0.3 Emerging Bus + Rail Architecture Planning/Requirements
- 0.4 Requirements for New/Transitional Onboard Architecture
- 0.5 Fleetwide MGR (and cellular data) for Bus
- 0.6 APCs Replacement/Upgrade
- 0.7 Fleetwide MGR (and cellular data) for Rail
- 0.8 Emerging Bus + Rail Architecture Implementation
- 0.9 Prepare for Onboard Systems Configuration Management
- 0.10 On-board Systems Configuration Management
- 0.11 Review and Refresh Bus + Rail On-board Architecture

CAD / AVL

- A.1 Prepare/Budget for ATMS II for Bus with Rail Consultant Support
- A.2 Procure Consultant Support for ATMS II for Bus with Rail Implementation
- A.3 Prepare for ATMS II for Bus and Rail Supplier Procurement
- A.4 ATMS II Supplier Procurement for Bus and Rail
- A.5 Implement ATMS II for Bus
- A.5.i Implement ATMS II for Rail

VIDEO

- V.1 DIMS
- V.2 Centralized Cloud-based VSS
- V.3 Video Streaming for Bus
- V.4 Video Streaming for Rail
- V.5 Video Tagging + Streaming Integration with ATMS II

YARD TOOLS & COMMUNICATION

- Y.1 Metro-developed Yard tool (bus underway, rail complete)
- Y.2 Upgrade WLAN in Bus Yards
- Y.3 Implement WLAN in Rail Yards
- Y.4 Prepare for Independent Bus + Rail Yard Management System
- Y.5 Implement Independent Bus + Rail Yard Management System
- Y.6 Metro-developed Yard Tool Refresh

ADVANCED TRAVELER INFORMATION SYSTEMS

- T.1 Multi-modal Alerts Pilot
- T.2 E-Signage Project
- T.3 Multi-modal Alerts
- T.4 GPS + Track Circuits and Beacons for Rail Vehicle Locations
- T.5 Rail-specific Prediction Engine
- T.6 Enhanced Multi-modal Real-time Aggregation System + Single GTFS-realtime Feed
- T.7 Webpages with RTPI
- T.8 NTCIP-compliant Station Signs with Common Sign Control
- T.9 Rail Public Address System Upgrade

SCADA

- S.1 Standardization of ARINC SCADA (except Green Line)
- S.2 Replicate SCADA in TDB
- S.3 SCADA Security Enhancements
- S.4 SCADA HMI for Maintenance Staff
- S.5 SCADA Message Gateway
- S.6 Standardization of ARINC SCADA (Green Line)

MAINTENANCE

- P.1 M3 Replacement

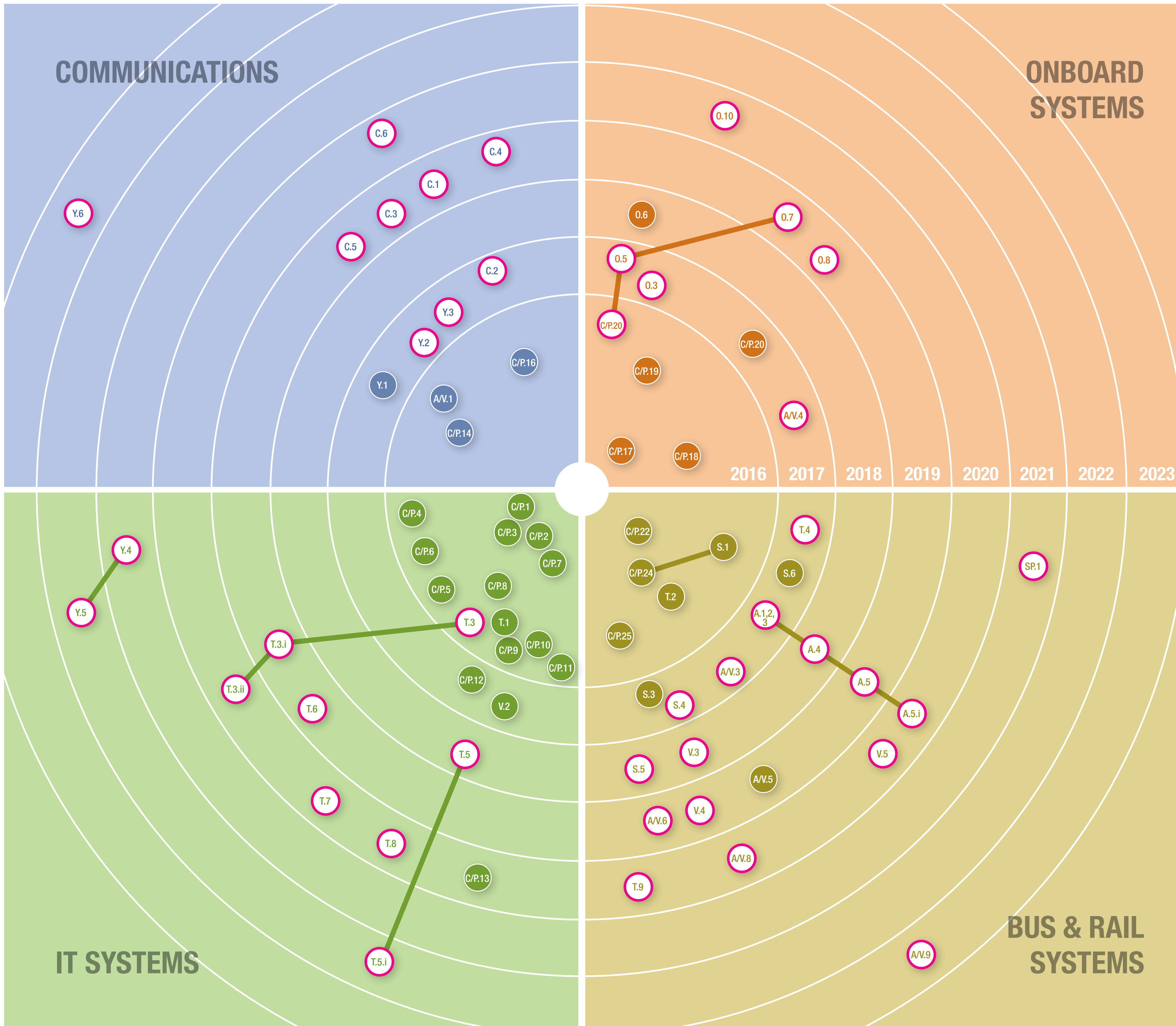
AUTONOMOUS VEHICLE

- **AV.1** LA County DSRC Pilot
- **AV.3** Plan for Connected Vehicle V2I Infrastructure
- **AV.4** Incorporate OEM Connected Vehicle Safety Functions into Bus Procurement
- **AV.5** Dynamic Rideshare Pilot Project
- **AV.6** CV-based Signal Priority Test Project
- **AV.7** Plan for Automated Operations in Guideways
- **AV.8** CV-based Signal Priority Pilot Project
- **AV.9** CV-based Signal Priority Implementation

RECOMMENDED PROJECTS

Metro

Figure 4 Overview of Current/Planned and Recommended Projects



CURRENT/PLANNED PROJECTS

IT SYSTEMS

C/P.1 Golden Gate
C/P.2 Business Intelligence
C/P.3 Integrated Corridor Management
C/P.4 Regional Assessment of Transportation Systems Operations
C/P.5 DIMS
C/P.6 HASTUS Upgrade
C/P.7 Real-Time Trip Planner
C/P.8 M3 Architecture
C/P.9 E-signage
C/P.10 ESOC Study
C/P.11 Regional ITS Architecture Update
C/P.12 RIITS Modernization
C/P.13 ESOC Construction
V.2 Centralized Cloud-Based VSS

BUS & RAIL SYSTEMS

AV.5 Dynamic Rideshare Pilot Project
C/P.22 Bus & Rail ITS Strategic Plan
C/P.24 Next Generation BSP
C/P.25 Platform Track Intrusion Detection System
S.1 Standardization of ARINC SCADA (except Green Line)
S.3 SCADA Security Enhancements
S.6 Standardization of ARINC SCADA (Green Line)
T.2 E-Signage Project
Y.1 Metro-developed Yard tool (bus underway, rail complete)

COMMUNICATIONS

AV.1 LA County DSRC Pilot
C/P.14 Cellular & LA-RICS Drive Test
C/P.16 Rail Yard WiFi
Y.2 Upgrade WLAN in Bus Yards
Y.3 Implement WLAN in Rail Yards

ONBOARD SYSTEMS

C/P.17 Farebox WPA2 Encryption
C/P.18 All Door Boarding Pilot
C/P.19 ATMS BSP Upgrade
C/P.20 Connected Fleet Vehicles & Facilities (includes Y.1/2)
C/P.21 Farebox Near Real-Tlime Communications
0.6 APCs Replacement/Upgrade
T.1 Multi-modal Alerts Pilot

RECOMMENDED PROJECTS

IT SYSTEMS

T.3 Multi-Modal Alerts
T.3.i Multi-Modal Alerts Renew or Replace
T.3.ii Alerts System Interface with ATMS II
T.5 Rail-Specific Prediction Engine
T.6 Enhanced Multi-Modal Real-Time Aggregation System & Single GTFS-Realtime Feed
T.7 Webpages with RTPI
T.8 NTCIP-Compliant Signs with Common Sign Control
Y.4 Prepare for Independent Bus & Rail Yard Management System (YMS)
Y.5 Implement Independent Bus & Rail YMS

BUS & RAIL SYSTEMS

A.1/2/3 ATMS II Planning
A.4 ATMS II Procurement
A.5 Implement ATMS II for Bus
A.5.i ATMS II Rail Implementation
AV.3 Plan for Connected Vehicle V2I Infrastructure
AV.6 Connected Vehicle-Based Signal Priority Test Project
AV.8 Connected Vehicle-Based Signal Priority Pilot Project
AV.9 Connected Vehicle-Based Signal Priority Implementation
S.4 SCADA HMI for Maintenance Staff
S.5 SCADA Message Gateway
SP.1 Update Bus & Rail ITS Strategic Plan
T.4 GPS + Track Circuits and Beacons for Rail Vehicle Locations
T.5.i Refresh Rail Prediction Engine
T.9 Rail PA System Upgrade
V.3 Video Streaming for Bus
V.4 Video Streaming for Rail
V.5 Video Tagging & Streaming Integration with ATMS II
Y.6 Metro-developed Yard Tool Refresh

COMMUNICATIONS

C.1 Drive Test (cell + LA-RICS)
C.2 Connected Vehicle: Establish (Commercial) Cellular Data Service for Bus Fleet
C.3 Establish VoIP for Bus (with radio backup)
C.4 Implement LA-RICS LMR in Tunnels for Sherriff
C.5 Connected Vehicle: Establish (Commercial) Cellular Data Service for Rail Fleet
C.6 Assess 5G Service + LA-RICS LMR for Bus and Rail Fleet and Update Comm. Plan

ONBOARD SYSTEMS

AV.4 Incorporate OEM Connected Vehicle Safety Functions into Bus Vehicle Procurements
0.3 Emerging Bus & Rail On-Board Architecture Planning & Requirements
0.5 Fleet Wide MGR (and cellular data) for Bus
0.7 Fleet-wide MGR (and cellular data) for Rail
0.8 Emerging Bus & Rail On-Board Architecture Implementation
0.10 Onboard System Configuration Management

4.3 Relationships between Fleet Systems

The many fleet systems operated by Metro have a number of interfaces and levels of integration both between each other and to other Metro non-fleet systems. As part of the Strategic Plan, an effort was made to document and summarize some of these interfaces and relationships. More detailed documentation of Metro's existing systems is available in Technical Memo for Task #1 – Needs Assessment. As a high level summary, **Figure 5** displays the system to system relationships between Metro fleet and supporting systems. **Figure 6** shows a more detailed view of the Transit Database (TDB), which plays a key role in aggregating and fusing key data elements from fleet and supporting systems.

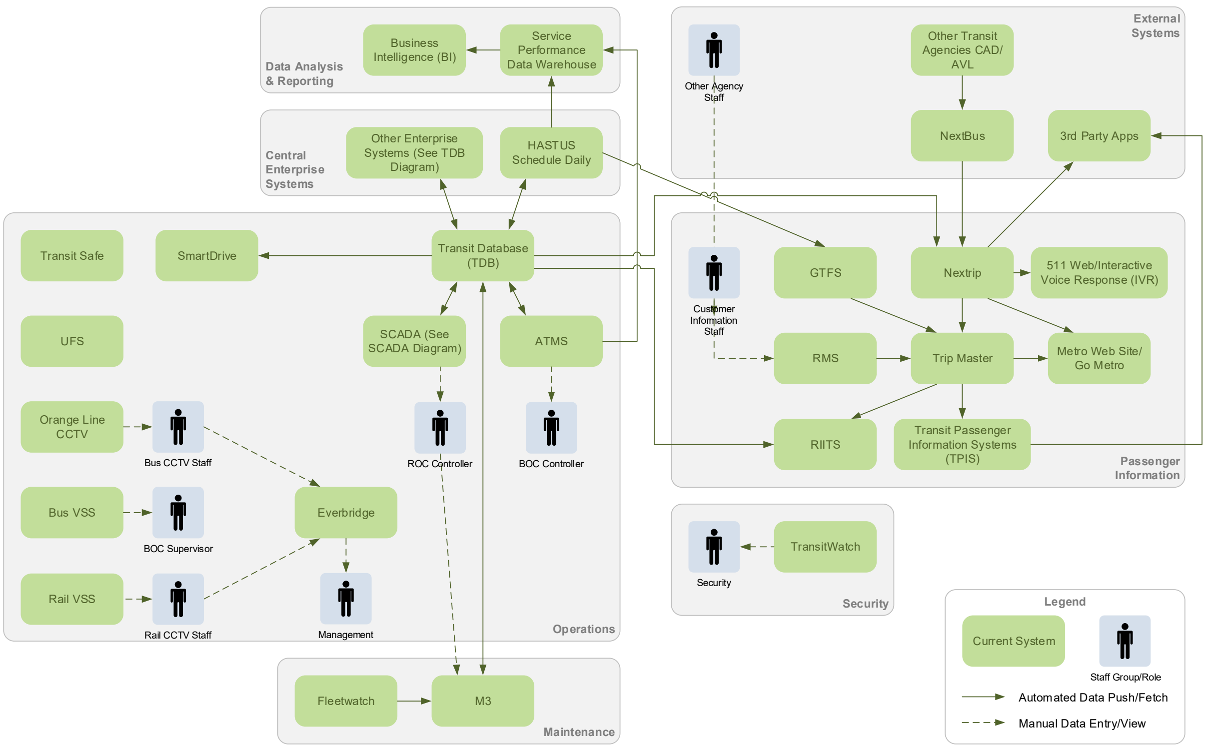


Figure 5 LA Metro Existing Fleet Systems Relationships and Interfaces

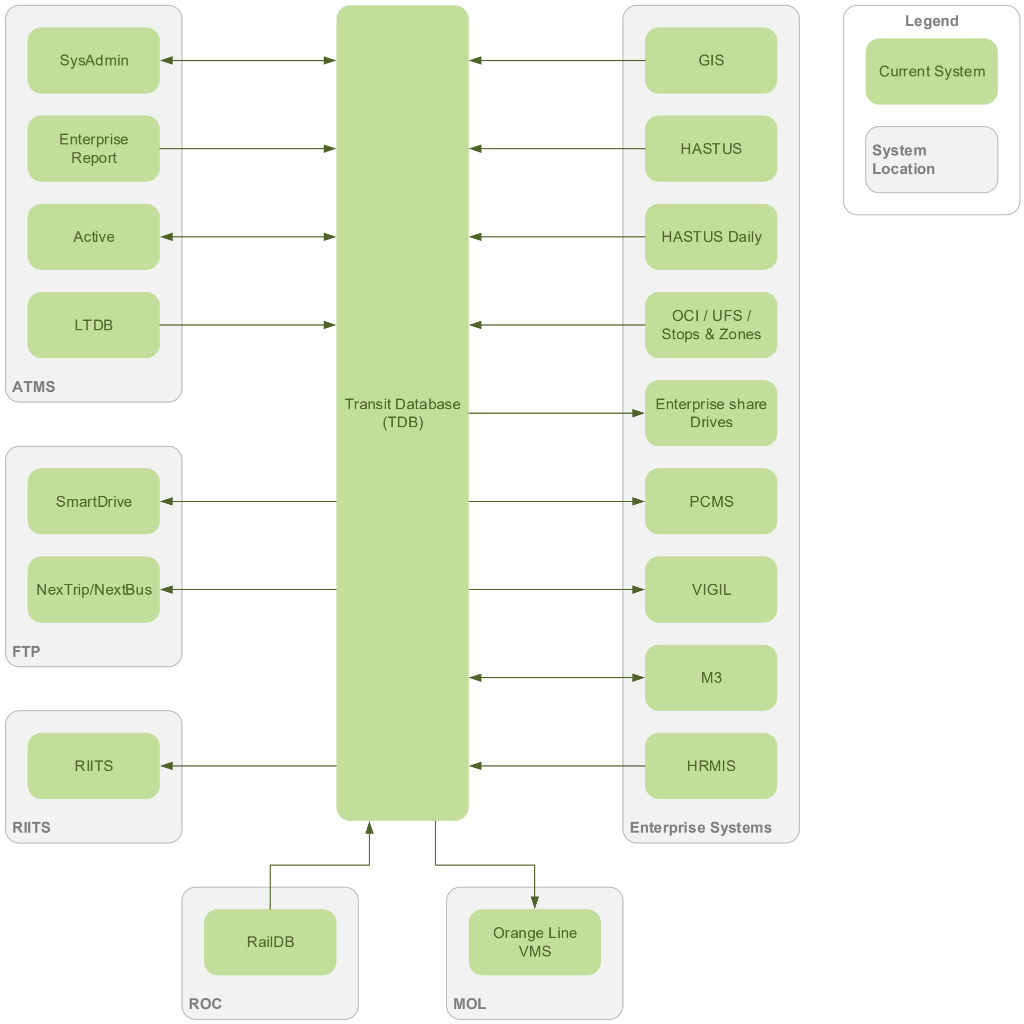


Figure 6 Illustration of TDB Interfaces

As recommended projects were developed for this Plan, the existing system to system relationships and interfaces were reviewed to determine where potential impacts might occur that would require:

- Integration of new fleet systems elements,
- Major upgrades or updates to existing fleet systems, and/or
- Minor upgrades or updates to existing fleet systems.

Figure 7, below, provides an updated version of Figure 5. Figure 7 highlights new and upgraded fleet system elements. In addition, red arrows or connections indicate new and updated interfaces that will likely need to be implemented by Metro during the design of the new fleet systems. Figure 7 is not intended to specify an architecture, but instead to give a high level overview of areas of potential impact when the recommended projects are implemented.

Commensurately, as the recommended projects are implemented, the TDB will require modification and updating. Metro's Business Intelligence (BI) and reporting tools will also require modifications. In particular, the new ATMS II will provide some substantially enhanced functionality that will require new interfaces with the TDB and Metro's reporting tools.

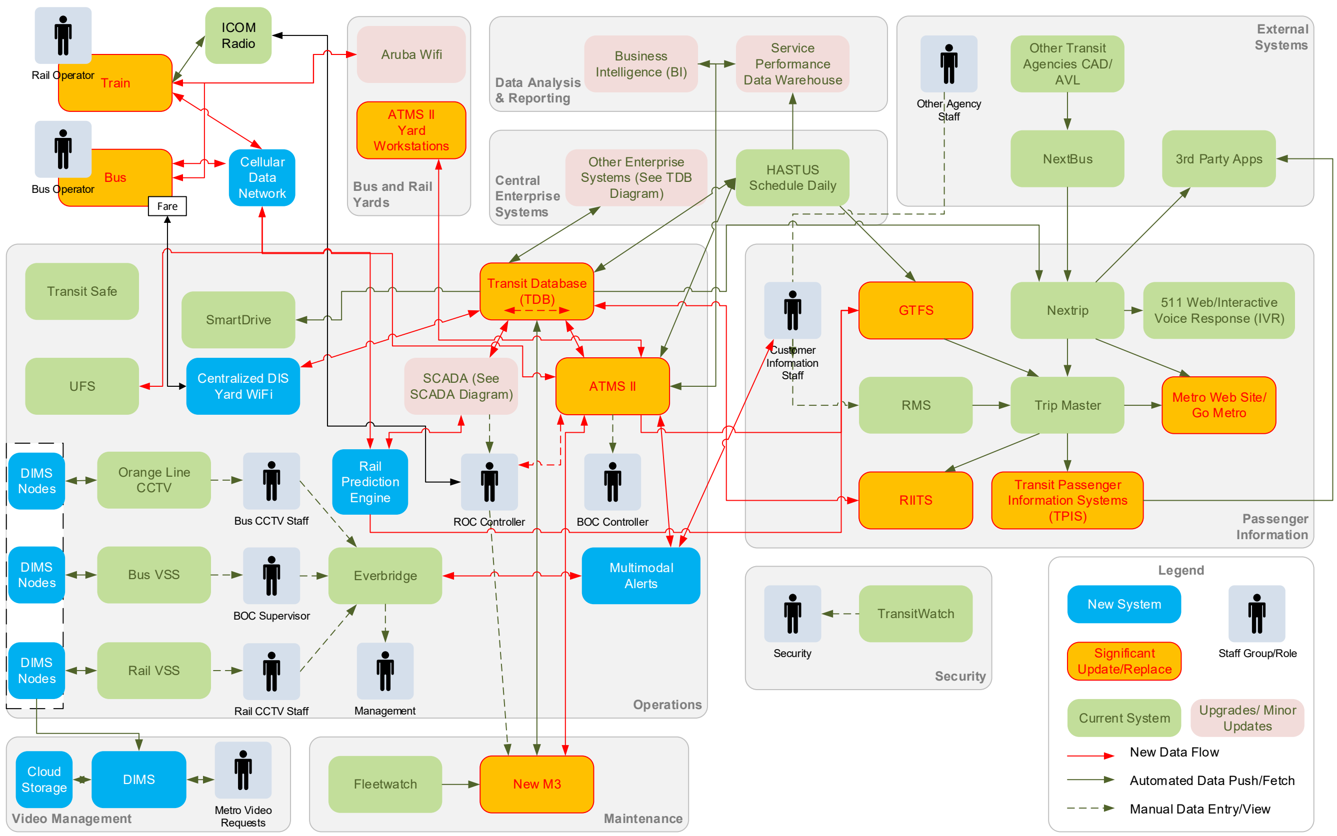


Figure 7 New and Upgraded Fleet Systems Relationships and Updated Interfaces

5 Rough Order of Magnitude Program Costs

The following are rough order of magnitude (ROM) costs that have been developed for the recommended projects. Some of the cost estimates are based on costs provided by vendors and some of the cost estimates are based on projected support required to procure, implement, and maintain the systems.

This section provides detailed ROM costs for each recommended project, including ten years of Operations and Maintenance costs.

5.1 Recommended Project Costs

5.1.1 ATMS II for Bus and Rail (A.1 thru A.5) and Emerging Trends On-board Architecture (O.2 thru O.10)

The following ROM costs for ATMS II were developed from inputs from CAD/AVL vendors and independent costs estimates. The ROM costs are based on the following assumptions:

- The recommended VoIP for bus voice communications and cellular network for bus and rail data communications costs are separate but the systems will be implemented either in advance of ATMS II Bus and Rail or in conjunction.
- The costs do not include further development required by Cubic to provide real-time TAP updates to the fareboxes.
- The recommended Rail Arrival Prediction Engine is implemented either in advance of ATMS II Rail or in conjunction.
- The recommended Multi-modal Service Alert System is implemented either in advance of ATMS II Bus and Rail or in conjunction.
- Bus fleet is 2,450 vehicles
- Rail fleet is 566 vehicles
- Project oversight costs are split between the Bus and Rail implementations
- Two full days of training for each CAD user.
- Two full days of training for each maintenance personnel.
- Two union FTEs for Metro oversight of installations.

Cost savings could be realized if the installation of the onboard ATMS equipment is performed by Metro staff, rather than the ATMS II contractor staff. The costs are exclusive of taxes, freight, and any applicable duties.

Table 1: ATMS II for Bus Order of Magnitude Costs

Vendor Costs

Hardware, On Bus	Quantity	Unit	Unit Cost	Extended Cost
MDT, dual purpose control head with farebox	2450	EA	$ 1,449	$ 3,550,098
On Board Processor	2450	EA	$ 1,865	$ 4,568,049
Mobile Gateway Router	2450	EA	$ 2,275	$ 5,572,909
Cellular Modem	2450	EA	$ 875	$ 2,143,750
VoIP	2450	EA	$ 660	$ 1,617,000
ATMS voice radio backup interface	2450	EA	$ 145	$ 355,010
ATMS data radio backup interface	2450	EA	$ 205	$ 502,170
WLAN Radio	2450	EA	$ 170	$ 416,500
GPS Receiver	2450	EA	$ 50	$ 122,500
Other AVL Hardware	2450	EA	$ 1,665	$ 4,079,250
State of the art APC Sensors	2450	EA	$ 2,581	$ 6,322,593
Internal LCD Signs for AVA and Passenger Information	2450	EA	$ 2,038	$ 4,992,075
Farebox Interface for single sign on, AVL data, farebox alarms	2450	EA	$ 120	$ 294,000
Headsign Interface	2450	EA	$ 130	$ 318,500
Silent Alarm Switch Interface	2450	EA	$ 75	$ 183,750
PA System Interface	2450	EA	$ 290	$ 710,500
Bus Signal Prioritization Interface	2450	EA	$ 50	$ 122,500
On Board Video System Interface for Real-Time Video Streaming	2450	EA	$ 90	$ 220,500
On Board Vehicle Health Monitoring	2450	EA	$ 290	$ 710,500
Vehicle Installation	2450	EA	$ 2,373	$ 5,814,667

Hardware, Road Supervisor Vehicles	Quantity	Unit	Unit Cost	Extended Cost
Cellular Modem	65	EA	$ 911	$ 59,200
On Board Processor	65	EA	$ 3,631	$ 236,000
Mobile Data Computer (MDC) or Tablet	65	EA	$ 2,773	$ 180,267
GPS Receiver	65	EA	$ 62	$ 4,000
Power Supply	65	EA	$ 105	$ 6,800
Mounting Hardware	65	EA	$ 560	$ 36,400

Hardware, Backend & Infrastructure	Quantity	Unit	Unit Cost	Extended Cost
CAD Workstations, BOC	24	EA	$ 3,397	$ 81,520
CAD Workstations, Emergency Dispatch Center	12	EA	$ 3,397	$ 40,760
Fixed End Servers	1	LOT	$ 887,853	$ 887,853
CAD Workstations, Divisions	11	EA	$ 4,105	$ 45,155
Yard Workstation	11	EA	$ 3,843	$ 42,268
Maintenance Workstations	11	EA	$ 3,895	$ 42,845
Contracted Services Workstations	3	EA	$ 4,195	$ 12,585
WLAN Interface to Arruba WiFi network in Yards	11	EA	$ 7,865	$ 86,515

Hardware, Spares	Quantity	Unit	Unit Cost	Extended Cost
10% Fixed Route Spares	245	EA	$ 8,184	$ 2,005,125
10% Road Supervisor Spares	7	EA	$ 2,530	$ 17,710
10% Infrastructure Spares	1	LOT	$ 60,540	$ 60,540

Software	Quantity	Unit	Unit Cost	Extended Cost
CAD Software including VoIP, BSP functionality, Hastus interface, bus bridge, real-time predictions	1	LOT	$ 2,426,490	$ 2,426,490
Interface to Cellular Data network, radio network	1	LOT	$ 181,040	$ 181,040
Video streaming during an SAS (if not included in standard product)	1	LOT	$ 75,600	$ 75,600

Project Management	Quantity	Unit	Unit Cost	Extended Cost
Project Management Staff	1	LOT	$ 4,337,935	$ 4,337,935
Project Management Meetings	1	LOT	$ 450,000	$ 450,000
Design Reviews	1	LOT	$ 509,350	$ 509,350
Training	1	LOT	$ 274,745	$ 274,745
Acceptance Tests	1	LOT	$ 529,470	$ 529,470
Documentation	1	LOT	$ 323,000	$ 323,000
Performance Bond	1	LOT	$ 3,171,894	$ 3,171,894
QA Person over life of installs	1	LOT	$ 400,000	$ 400,000

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LOT		$ 150,000
Implementation Support	1	LOT		$ 1,800,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight PM	5	EA	$ 150,000	$ 450,000
Project Oversight Assistants	2	EA	$ 100,000	$ 600,000
CAD User Training	70	LOT	$ 1,156	$ 93,097
Vehicle Maintenance Training Development	22	LOT	$ 723	$ 18,287
Integration and interfaces	5	EA	$ 20,000	$ 100,000

		Capital
Subtotal Vendor Costs		$ 59,141,887
Contingency	10%	$ 5,914,189
Subtotal Consultant Costs		$ 1,950,000
Subtotal Agency Costs		$ 1,261,383
Total		**$ 68,267,000**

Support Costs	Quantity	Unit	Unit Cost	Extended Cost
Vendor Annual Cost for Post Warranty Hardware and software support	10	EA	$ 1,300,000	$ 13,000,000
Agency Maintenance Costs	10	EA	$ 1,032,000	$ 10,320,000

Hardware Refresh Costs	Quantity	Unit	Unit Cost	Extended Cost
Server replacements after 5 years	1	LOT	$6,000,000	$6,000,000

	10 Year O+M
Total	**$ 29,320,000**

Table 2: Emerging Trends On-board Architecture for Bus Order of Magnitude Costs

Vendor Costs	Quantity	Unit	Unit Cost	Extended Cost
Separate IVU Comparison Testing Equipment	2	EA	$ 10,000	$ 20,000
Field install	1	EA	$ 2,500	$ 2,500
Bench Test Setup & Equipment	1	EA	$ 35,000	$ 35,000
Testing Software	1	LS	$ 100,000	$ 100,000
Acceptance Tests	1	LS	$ 200,000	$ 200,000
Documentation	1	LS	$ 100,000	$ 100,000

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LS	$ 250,000	$ 250,000
Implementation Support	1	LS	$ 500,000	$ 500,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	2	LS	$ 150,000	$ 300,000
Agency CM Efforts & On-Board Architecture	5	EA	$ 75,000	$ 375,000
Testing	5	EA	$ 86,500	$ 432,500

		Capital
Subtotal Vendor Costs		$ 457,500
Contingency	10%	$ 120,750
Subtotal Consultant Costs		$ 750,000
Subtotal Agency Costs		$ 1,107,500
Total		**$ 2,436,000**

Support Costs				Annual Cost
Vendor Annual Cost for Post Warranty Hardware and software support	1	LS	10%	$ 45,750
Agency Staff - On-Going Architecture Maintenance	0.5	LS	$ 150,000	$ 75,000
				10 Year O+M
	Total			**$ 1,208,000**

Table 3: ATMS II for Rail Order of Magnitude Costs

Vendor Costs

Hardware, On Rail Vehicle	Quantity	Unit	Unit Cost	Extended Cost
MDT	566	EA	$ 2,503	$ 1,416,600
On Board Processor	566	EA	$ 1,896	$ 1,072,920
Router	566	EA	$ 2,400	$ 1,358,415
Cellular Modem	566	EA	$ 895	$ 506,570
WLAN Radio	566	EA	$ 1,660	$ 939,560
GPS Receiver	566	EA	$ 50	$ 28,300
Other AVL Hardware	566	EA	$ 3,535	$ 2,000,880
APC Sensors	566	EA	$ 5,799	$ 3,282,380
Internal LCD Signs for AVA and Passenger Information	566	EA	$ 2,151	$ 1,217,540
Headsign Interface	566	EA	$ 130	$ 73,580
Silent Alarm Switch Interface	566	EA	$ 75	$ 42,450
PA System Interface	566	EA	$ 415	$ 234,890
On Board Video System Interface for Real-Time Video Streaming	566	EA	$ 90	$ 50,940
On Board Vehicle Health Monitoring	566	EA	$ 320	$ 181,120
Vehicle Installation	566	EA	$ 3,788	$ 2,144,260

Hardware, Field Supervisor Vehicles	Quantity	Unit	Unit Cost	Extended Cost
Cellular Modem	32	EA	$ 2,870	$ 91,840
On Board Processor	32	EA	$ 2,950	$ 94,400
Removable Mobile Data Computer (MDC) or Tablet	32	EA	$ 2,253	$ 72,107
GPS Receiver	32	EA	$ 50	$ 1,600
Power Supply	32	EA	$ 85	$ 2,720
Mounting Hardware	32	EA	$ 455	$ 14,560

Hardware, Infrastructure	Quantity	Unit	Unit Cost	Extended Cost
CAD Workstations, ROC	9	EA	$ 5,377	$ 48,390
CAD Workstations, Rail Divisions	9	EA	$ 4,457	$ 40,110
Yard Workstation	9	EA	$ 4,457	$ 40,110
Maintenance Workstations	9	EA	$ 4,543	$ 40,890
WLAN Interface to Arruba Wifi Network at Yards	9	EA	$ 13,660	$ 122,940
Fixed End Servers	1	LOT	$ 1,053,970	$ 1,053,970

Hardware, Spares	Quantity	Unit	Unit Cost	Extended Cost
10% Rail Vehicle Spares	57	EA	$ 8,370	$ 477,087
10% Field Supervisor Spares	4	EA	$ 3,353	$ 13,413

Software	Quantity	Unit	Unit Cost	Extended Cost
CAD Software including TSP, Interface to Hastus, bus bridge, real-time predictions	1	LOT	$ 389,120	$ 389,120
Interface to Cellular Data network	1	LOT	$ 127,690	$ 127,690
Video streaming during an SAS (if not included in standard product)	1	LOT	$ 25,200	$ 25,200

Project Management	Quantity	Unit	Unit Cost	Extended Cost
Project Management Staff	1	LOT	$ 1,821,973	$ 1,821,973
Project Management Meetings	1	LOT	$ 125,000	$ 125,000
Design Reviews	1	LOT	$ 254,675	$ 254,675
Training	1	LOT	$ 116,070	$ 116,070
Acceptance Tests	1	LOT	$ 259,823	$ 259,823
Documentation	1	LOT	$ 129,447	$ 129,447
Performance Bond	1	LOT	$ 356,390	$ 356,390

Consultant Costs			Unit Cost	Extended Cost
Engineering	1	LOT		$ 250,000
Implementation Support	1	LOT		$ 600,000

Agency Costs			Unit Cost	Extended Cost
Project Oversight	4	EA	$ 150,000	$ 900,000
CAD User Training	54	LOT	$ 1,156	$ 71,817

	Capital
Subtotal Vendor Costs	$ 20,269,929
Subtotal Consultant Costs	$ 850,000
Contingency	$ 2,026,993
Subtotal Agency Costs	$ 971,817

Total	**$ 24,119,000**

O&M

Support Costs			Unit Cost	Extended Cost
Vendor Annual Cost for Post Warranty Hardware and software support	10	EA	$ 420,000	$ 4,200,000
Agency Maintenance Costs	10		$ 860,000	$ 8,600,000

Hardware Refresh Costs				
Server replacements after 5 years			$2,000,000	$ 2,000,000

	10 Year O+M
Total	**$ 14,800,000**

Table 4: Emerging Trends On-board Architecture for Rail Order of Magnitude Costs

Vendor Costs	Quantity	Unit	Unit Cost	Extended Cost
Separate IVU Comparison Testing Equipment	1	EA	$ 10,000	$ 10,000
Field install	1	EA	$ 2,500	$ 2,500
Bench Test Setup & Equipment	1	EA	$ 35,000	$ 35,000
Testing Software	1	LS	$ 50,000	$ 50,000
Acceptance Tests	1	LS	$ 100,000	$ 100,000
Documentation	1	LS	$ 50,000	$ 50,000

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LS	$ 150,000	$ 150,000
Implementation Support	1	LS	$ 175,000	$ 175,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	0.5	LS	$ 150,000	$ 75,000
Agency CM Efforts & On-Board Architecture	3	EA	$ 75,000	$ 225,000
Testing	3	EA	$ 86,500	$ 259,500

		Capital
Subtotal Vendor Costs		$ 247,500
Contingency	10%	$ 57,250

Subtotal Consultant Costs	$ 325,000
Subtotal Agency Costs	$ 559,500
Total	**$ 1,189,000**

Support Costs				Annual Cost
Vendor Annual Cost for Post Warranty Hardware and software support	1	LS	5%	$ 12,250
Agency Staff - On-Going Architecture Maintenance	0.5	LS	$ 150,000	$ 75,000

	10 Year O+M
Total	**$ 874,000**

5.1.2 VoIP System for Bus (C.3)

The following ROM costs for implementation of a Voice over Internet Protocol System are based on the following assumptions:

- Metro will continue to use its existing voice radio as a backup to the VoIP system for five years.
- 2450 bus fleet size, 200 portables for road supervisors and maintenance staff
- The cost is exclusive of taxes, freight, and any applicable duties.

Table 5: VoIP for Bus with Radio Backup Order of Magnitude Costs

Cellular Vendor	Quantity	Unit	Unit Cost	Extended Cost
Fixed Route Vehicles - Cellular Card	2450	EA	$ 150	$ 367,500
Non-Revenue Vehicles - Cellular Card	65	EA	$ 150	$ 9,750
Portables and Accessories	200	EA	$ 2,800	$ 560,000
Central Site Equipment	1	EA	$ 250,000	$ 250,000
Spares	1	LOT	10%	$ 93,725
Project Management, Eng., Overhead	1	LOT	30%	$ 356,175
Training	10	PERSONS	$ 2,500	$ 25,000
Integration with CAD (Central Equipment)	1	LOT	$ 1,000,000	$ 1,000,000
Integration with CAD (On-Board Equipment)	1	LOT	$ 500,000	$ 500,000
Warranty (5 Years + 5 Years Post-Warranty Call Support)	1	LOT	15%	$ 178,088
Contingency	1	LOT	20%	$ 668,000
Performance Bond	1	LOT	2%	$ 67,000

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LOT	10%	$ 407,500
Implementation Support	1	LOT	10%	$ 407,500
Contingency	1	LOT	10%	$ 82,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	1	FTE	$ 100,000	$ 100,000

	Capital
Subtotal Cellular Vendor	$ 4,075,000
Subtotal Consultant	$ 897,000
Subtotal Agency Costs	$ 100,000
Total	**$ 5,072,000**

O&M

Support Costs

	Quantity	Unit	Monthly Cost	Extended Cost
Leased Data Communications (fixed-route + non-revenue + portables)	2715	EA	$ 17	$ 5,538,600
Radio System Maintenance	1	FTE	$ 7,000	$ 840,000
Radio Site Leases (for five years)	6	EA	$ 10,000	$ 3,600,000
Agency Oversight (.1 FTE for 10 years)	0.1	FTE	$ 10,000	$ 100,000

10 Year O+M

Total	**$**	**10,079,000**

5.1.3 Data Communications System for Bus and Rail (C.2 + C.5)

The following ROM costs for implementation of a new data communication system are based on the following assumptions:

- Mobile gateway routers have been installed on the entire fleet.
- The cost is exclusive of taxes, freight, and any applicable duties.
- Leased data communications cost for bus includes service for 2450 buses, 65 non-revenue vehicles, 200 portables
- Leased data communications cost for rail includes service for 566 vehicles and 32 non-revenue vehicles

Table 6: Commercial Cellular Data System for Bus Order of Magnitude Costs

Cellular Vendor	Quantity	Unit	Unit Cost	Extended Cost
Fixed Route Vehicles - Cellular Card (provide, install, commission)	2450	EA	$ 150	$ 367,500
Non-Revenue Vehicles - Cellular Card (provide, install, commission)	65	EA	$ 150	$ 9,750
Central Site Equipment	1	EA	$ 100,000	$ 100,000
Spares (10%)	1	LOT	10%	$ 47,725
Project Management Engineering, Overhead	1	LOT	30%	$ 143,175
Training	10	PERSONS	$ 2,500	$ 25,000
Integration with CAD (Central Equipment)	1	LOT	$ 500,000	$ 500,000
Integration with CAD (On-Board Equipment)	2515	LOT	$ 200	$ 503,000
Warranty (5 Years + 5 Years Post-Warranty Call Support)	1	LOT	15%	$ 71,588
Contingency	1	LOT	10%	$ 177,000
Performance Bond	1	LOT	2%	$ 35,000

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LOT	10%	$ 198,000
Implementation Support	1	LOT	10%	$ 198,000
Contingency	1	LOT	10%	$ 40,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	1	FTE	$ 100,000	$ 100,000

	Capital
Subtotal Cellular Vendor	$ 1,980,000
Subtotal Consultant	$ 436,000
Subtotal Agency Costs	$ 100,000
Total	**$ 2,516,000**

O&M

Support Costs

	Quantity	Unit	Monthly Cost	Extended Cost
Leased Data Communications (Fixed + non-revenue + portables)	2715	EA	$ 15	$ 4,887,000
Leased Backhaul Circuits	4	EA	$ 300	$ 144,000

System Maintenance	1	LOT	$ 2,000	$ 240,000
Agency Oversight (.1 FTE for10 years)	0.1	FTE	$ 10,000	$ 100,000

	10 Year O+M
Total	**$ 5,371,000**

Table 7: Commercial Cellular Data System for Rail Order of Magnitude Costs

Cellular Vendor	Quantity	Unit	Unit Cost	Extended Cost
Rail Vehicles - Cellular Card (provide, install, commission)	566	EA	$ 150	$ 84,900
Non-Revenue Vehicles - Cellular Card (provide, install, commission)	32	EA	$ 150	$ 4,800
Central Site Equipment	1	EA	$ 50,000	$ 50,000
Spares	1	LOT	10%	$ 8,970
Project Management, Eng., Overhead	1	LOT	30%	$ 41,910
Training	9	PERSONS	$ 2,500	$ 22,500
Integration with CAD (Central Equipment)	1	LOT	$ 100,000	$ 100,000
Integration with CAD (On-Board Equipment)	1	LOT	$ 5,000	$ 5,000
Warranty (5 Years + 5 Years Post-Warranty Call Support)	1	LOT	15%	$ 20,955
Contingency	1	LOT	10%	$ 34,000
Performance Bond	1	LOT	2%	$ 7,000

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LOT	10%	$ 38,000
Implementation Support	1	LOT	10%	$ 38,000
Contingency	1	LOT	10%	$ 8,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	0.5	FTE	$ 100,000	$ 50,000

	Capital
Subtotal Cellular Vendor	$ 380,000
Subtotal Consultant	$ 84,000
Subtotal Agency Costs	$ 50,000
Total	**$ 514,000**

Support Costs

	Quantity	Unit	Monthly Cost	Extended Cost
Leased Data Communications	598	EA	$ 15	$ 1,076,400
Leased Backhaul Circuits	1	EA	$ 300	$ 36,000
System Maintenance	1	LOT		$ -
Agency Oversight (0.1 FTE for10 years)	0.1	FTE	$ 10,000	$ 100,000

	10 Year O+M
Total	**$ 1,212,000**

5.1.4 Yard Management (Y.4 + Y.5)

The following ROM costs for implementation of a Bus/Rail Yard Management System are based on the following assumptions:

- Annual storage and server fee @ $1200/mo.
- 1 FTE for 2 years for Metro project oversight, design, and implementation support.
- 0.5 union FTE for 2 years for testing and support.
- 0.5 union FTE for operation and maintenance.
- Consultant support for design, specifications, and implementation support.
- The cost is exclusive of taxes, freight, and any applicable duties.

Table 8: Independent Yard Management Tool for Bus and Rail Order of Magnitude Costs

Vendor Costs

Hardware, Field	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
Additional Location Devices Buses	2450	EA	$ 1,500	$ 3,675,000
Additional Location Devices Rail	566	EA	$ 1,500	$ 849,000

Hardware, Backend & Infrastructure	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
In-house Data Aggregation & Yard Comm Servers	17	EA	$ 10,000	$ 170,000

Software	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
Yard Management Software Core	1	LS	$ 1,500,000	$ 1,500,000
Customization of Functions	1	LS	$ 1,000,000	$ 1,000,000
Yard Setup	1	LS	$ 600,000	$ 600,000
ATMS II Integration	1	LS	$ 1,750,000	$ 1,750,000

Project Management	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
Project Management Staff	1	LS	$ 100,000	$ 100,000
Design Reviews	1	LS	$ 250,000	$ 250,000
Training	1	LS	$ 100,000	$ 100,000
Acceptance Tests	1	LS	$ 250,000	$ 250,000

Consultant Costs	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
Design and Specifications	1	LS	$ 50,000	$ 50,000
Implementation Support	1	LS	$ 50,000	$ 50,000

Agency Costs	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
Project Oversight, Design & Implementation Support (2 years)	1	LS	$ 200,000	$ 200,000

Testing and Support (2 years)	0.5	EA	$ 86,580	$ 43,290

		Capital Cost
Subtotal Vendor Costs		$ 10,244,000
Subtotal Consultant Costs		$ 100,000
Contingency	10%	$ 1,034,400
Subtotal Agency Costs		$ 243,290
Total		**$ 11,622,000**

O&M

Lease Costs	Quantity	Unit	Unit Cost	Extended Cost
Cloud-based server	1	LS	$ 14,400	$ 14,400

Support Costs	Quantity	Unit	Unit Cost	Extended Cost
Vendor Annual Cost for Post Warranty Hardware and software support	1	LS	5%	$ 512,200
Agency Maintenance Costs	0.5	LS	$ 86,580	$ 43,290

	10 Year O+M
Total	**$ 5,699,000**

5.1.5 GPS + Track Wayside Circuits (TWC) and Beacons for Rail Vehicle Locations (T.4)

The following ROM costs for implementation of a GPS, TWC, and beacon System for improved rail vehicle location predictions are based on the following assumptions:

- 0.5 FTE over 1 year for Metro project oversight.
- 1 union FTE over 1 year for Testing.
- 0.5 union FTE for operation and maintenance.
- The cost is exclusive of taxes, freight, and any applicable duties.

Table 9: GPS with Track Wayside Circuits and Beacons Order of Magnitude Costs

Vendor Costs

Hardware, Field	Quantity	Unit	Unit Cost	Extended Cost
Rail Car GPS Units	566	EA	$ 1,500	$ 849,000
Rail Track Beacons	566	EA	$ 500	$ 283,000

Hardware, Backend & Infrastructure	Quantity	Unit	Unit Cost	Extended Cost
Track Wayside Circuits	20	EA	$ 20,000	$ 400,000
Beacons	40	EA	$ 4,500	$ 180,000

Hardware, Spares	Quantity	Unit	Unit Cost	Extended Cost
Beacons	10	EA	$ 4,500	$ 45,000

Software	Quantity	Unit	Unit Cost	Extended Cost
Data fusion software	1	EA	$ 200,000	$ 200,000

Project Management	Quantity	Unit	Unit Cost	Extended Cost
Project Management Staff	1	LS	$ 100,000	$ 100,000
Training			5%	$ 10,000
Acceptance Tests			10%	$ 20,000
Documentation			5%	$ 10,000

Warranty (Software)	Quantity	Unit	Unit Cost	Extended Cost
Software (5 years)	5	LOT	5%	$ 50,000
Hardware (5 years)	5	LOT	1%	$ 85,600

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LS	$ 50,000	$ 50,000
Implementation Support	1	LS	$ 75,000	$ 75,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	0.5	EA	$ 100,000	$ 50,000
Testing/Install of TWC & Beacons	1	EA	$ 86,580	$ 86,580
Integration and interfaces			10%	$ 20,000

		Capital
Subtotal Vendor Costs		$ 2,252,600
Subtotal Consultant Costs		$ 125,000
Contingency	10%	$ 237,760
Subtotal Agency Costs		$ 156,580
Total		**$ 2,772,000**

O&M

Support Costs	Quantity	Unit	Unit Cost	Extended Cost
Vendor Annual Cost for Post Warranty Hardware and software support	1	LS	$ 56,315	$ 56,315
Agency Maintenance Costs	0.5	EA	$ 86,580	$ 43,290

Hardware Refresh Costs (One Time)	Quantity	Unit	Unit Cost	Extended Cost
Field hardware maintenance	1	LS	$ 225,260	One time

	10 Year O+M
Total	**$ 940,000**

5.1.6 Rail-specific Arrival Prediction Engine (T.5)

The following ROM costs for implementation of a Rail Arrival Prediction System are based on the following assumptions:

- 0.2 FTE over 1.5 years for Metro project oversight.
- 0.05 union FTE over 1 year for testing.
- 0.5 union FTE for operation and maintenance.
- The cost is exclusive of taxes, freight, and any applicable duties.

Table 10: Rail-specific Prediction Engine Order of Magnitude Costs

Vendor Costs

Software	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
Central System - New Prediction Engine	1	EA	$ 200,000	$ 200,000

Project Management	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
Project Management Staff	0.5	LS	$ 100,000	$ 50,000
Design Reviews			10%	$ 20,000
Training			5%	$ 10,000
Acceptance Tests			10%	$ 20,000
Documentation			5%	$ 10,000
Performance Bond				$ 9,300

Consultant Costs	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
Engineering	1	LS	$ 35,000	$ 35,000
Implementation Support	1	LS	$ 75,000	$ 75,000

Agency Costs	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
Project Oversight	0.3	EA	$ 150,000	$ 45,000
Testing	0.05	EA	$ 86,580	$ 4,329
Integration and interfaces			20%	$ 40,000

		Capital
Subtotal Vendor Costs		$ 319,300
Subtotal Consultant Costs		$ 110,000
Contingency	10%	$ 42,930
Subtotal Agency Costs		$ 89,329
Total		**$ 562,000**

Support Costs	Quantity	Unit	Unit Cost	Extended Cost
Vendor Annual Cost for Post Warranty Hardware and software support			10%	$ 31,930
Agency Maintenance Costs	0.25	EA	$ 86,580	$ 21,645

	10 Year O+M
Total	**$ 536,000**

5.1.7 Public Address System Upgrade for Rail (T.9)

The following ROM costs for implementation of a PA System Upgrade are based on the following assumptions:

- 104 rail stations to be equipped.
- 0.2 FTE over 3 years for Metro project oversight.
- 0.05 union FTE over 1 year for Testing.
- 0.5 union FTE for operation and maintenance.
- The cost is exclusive of taxes, freight, and any applicable duties.

Table 11: Public Address System Upgrade for Rail Order of Magnitude Costs

Vendor Costs

Hardware, Field	Quantity	Unit	Unit Cost	Extended Cost
Station Upgrades	104	EA	$ 10,000	$ 1,040,000

Hardware, Spares	Quantity	Unit	Unit Cost	Extended Cost
Spares			5%	$ 52,000

Software	Quantity	Unit	Unit Cost	Extended Cost
Central System	1	LS	$ 235,000	$ 235,000

Project Management	Quantity	Unit	Unit Cost	Extended Cost
Project Management Staff	1	LS	$ 100,000	$ 100,000
Design Reviews			10%	$ 23,500
Training			5%	$ 11,750
Acceptance Tests			10%	$ 23,500
Documentation			5%	$ 11,750
Performance Bond				$ 77,250

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LS	$ 25,000.00	$ 25,000
Implementation Support	1	LS	$ 125,000.00	$ 125,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	0.6	EA	$ 100,000	$ 60,000
Testing	0.05	EA	$ 86,580	$ 4,329
Integration and interfaces			10%	$ 23,500

			Capital
Subtotal Vendor Costs			$ 1,574,750
Subtotal Consultant Costs			$ 150,000
Contingency		10%	$ 172,475
Subtotal Agency Costs			$ 87,829
Total			**$ 1,985,000**

Support Costs	Quantity	Unit	Unit Cost	Extended Cost
Vendor Annual Cost for Post Warranty Hardware and software support			10%	$ 157,475
Agency Maintenance Costs	0.5	EA	$ 86,580	$ 43,290

	10 Year O+M
Total	**$ 2,008,000**

5.1.8 Multi-modal Alerts System (T.3)

The following ROM costs for implementation of an Improved Service Alerting System are based on the following assumptions:

- Cloud-based service cost of $1200/mo. is assumed. However, the Alert System could be run on existing Metro servers.
- 0.2 FTE over 3 years for Metro project oversight.
- 0.05 union FTE over 1 year for Testing.
- 1 union FTE for operation and maintenance unless cloud-based service is used.
- The cost is exclusive of taxes, freight, and any applicable duties.

Table 12: Multi-modal Alerts System Order of Magnitude Costs

Vendor Costs

Software	Quantity	Unit	Unit Cost	Extended Cost
Central System Upgrades	1	EA	$ 285,000	$ 285,000

Project Management	Quantity	Unit	Unit Cost	Extended Cost
Project Management Staff	0.3	LS	$ 100,000	$ 30,000
Design Reviews			5%	$ 15,000
Training			10%	$ 30,000
Acceptance Tests			5%	$ 15,000
Documentation			5%	$ 15,000
Performance Bond				$ 27,000

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LS	$ 30,000	$ 30,000
Implementation Support	1	LS	$ 45,000	$ 45,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	0.6	EA	$ 100,000	$ 60,000
Testing	0.05	EA	$ 86,580	$ 4,329
Integration and interfaces	1	LS	$ 30,000	$ 30,000

		Capital
Subtotal Vendor Costs		$ 417,000
Subtotal Consultant Costs		$ 75,000
Contingency	10%	$ 49,200
Subtotal Agency Costs		$ 94,329
Total		**$ 636,000**

Lease Costs	Quantity	Unit	Unit Cost	Extended Cost
Cloud-based server	12	MOS	$ 1,200	$ 14,400

Support Costs	Quantity	Unit	Unit Cost	Extended Cost
Vendor Annual Cost for Post Warranty Hardware and software support			15%	$ 45,000
Agency Maintenance Costs	0.5	EA	$ 86,580	$ 43,290

	10 Year O+M
Total	**$ 1,027,000**

5.1.9 Enhanced Multi-modal Aggregation System with Single GTFS-realtime Feed (T.6)

The following ROM costs for implementation of Traveler Information Aggregation System are based on the following assumptions:

- Cloud-based service cost of $2400/mo. is assumed. However, the Aggregation System could be run on existing Metro servers
- .2 FTE over 2 years for Metro project oversight.
- 0.05 union FTE over 1 year for Testing.
- 1 FTE over 1 year for Integration and Interfaces
- 0.5 union FTE for operation and maintenance.
- The cost is exclusive of taxes, freight, and any applicable duties.

Table 13: Enhanced Multi-modal Aggregation System with Single GTFS-realtime Feed

Vendor Costs

Software	Quantity	Unit	Unit Cost	Extended Cost
System Upgrades - Aggregation	1	LS	$ 850,000	$ 850,000
System Upgrades - GTFS-realtime Feed	1	LS	$ 100,000	$ 100,000

Project Management	Quantity	Unit	Unit Cost	Extended Cost
Project Management Staff	1	LS	$ 95,000	$ 95,000
Design Reviews			5%	$ 47,500
Training			5%	$ 47,500
Acceptance Tests			5%	$ 47,500
Documentation			5%	$ 47,500
Performance Bond				$ 52,000

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LS	$ 95,000	$ 95,000
Implementation Support	1	LS	$ 142,500	$ 142,500

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	0.4	EA	$ 100,000	$ 40,000
Training				$ -
Testing	0.05	EA	$ 86,580	$ 4,329
Integration and interfaces	1	LS	$ 150,000	$ 150,000

	Capital
Subtotal Vendor Costs	$ 1,287,000

Subtotal Consultant Costs		$	237,500
Contingency	10%	$	152,450
Subtotal Agency Costs		$	194,329
Total		**$**	**1,871,000**

Lease Costs	Quantity	Unit	Unit Cost	Extended Cost
Cloud-based server	12	MOS	$ 2,400	$ 28,800

Support Costs	Quantity	Unit	Unit Cost	Extended Cost
Vendor Annual Cost for Post Warranty Hardware and software support	1	YR	$ 64,350.00	$ 64,350
Agency Maintenance Costs	0.3	EA	$ 86,580	$ 25,974

	10 Year O+M
Total	**$ 1,191,000**

5.1.10 Webpages with Real-time Passenger Information (T.7)

The following ROM costs for implementation of upgrades to the existing Metro web page for improved real-time passenger information are based on the following assumptions:

- No additional cost for cloud-based service, as current hosting service will be used. However, the Dissemination System could be run on existing Metro servers.
- 0.1 FTE over 1 year for Metro project oversight.
- 0.05 union FTE over 1 year for Testing.
- 0.25 FTE over 1 year for Integration and Interfaces
- 0.5 union FTE for operation and maintenance.
- The cost is exclusive of taxes, freight, and any applicable duties.

Table 14: Webpages with Real-time Passenger Information Order of Magnitude Costs

Vendor Costs

Software	Quantity	Unit	Unit Cost	Extended Cost
System Upgrades	1	EA	$ 150,000	$ 150,000

Project Management	Quantity	Unit	Unit Cost	Extended Cost
Project Management Staff	1	LS	$ 40,000	$ 40,000
Design Reviews			10%	$ 15,000
Training			5%	$ 7,500
Acceptance Tests			10%	$ 15,000
Documentation			5%	$ 7,500
Performance Bond				$ 4,700

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LS	$ 20,000.00	$ 20,000
Implementation Support	1	LS	$ 40,000.00	$ 40,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	0.1	EA	$ 100,000	$ 10,000
Testing	0.05	EA	$ 86,580	$ 4,329
Integration and interfaces	0.25	EA	$ 150,000	$ 37,500

		Capital
Subtotal Vendor Costs		$ 239,700
Subtotal Consultant Costs		$ 60,000
Contingency	10%	$ 29,970

Subtotal Agency Costs	$	51,829
Total	**$**	**381,000**

Support Costs	Quantity	Unit	Unit Cost	Extended Cost
Agency Maintenance Costs	0.5	EA	$ 86,580	$ 43,290

	10 Year O+M
Total	**$ 433,000**

5.1.11 NTCIP-compliant Signs with Common Sign Control (T.8)

The following ROM costs for implementation of NTCIP-compliant signs at rail and bus stations and park-and-rides with a common sign control are based on the following assumptions:

- 88 new signs. (85% of 104 signs) It is assumed that 15% are already compliant.
- Unit cost assumes two signs per platform and two platforms per station.
- 0.5 FTE over 2 years for Metro project oversight.
- 0.1 union FTE over 1 year for Testing.
- 0.25 FTE over 1 year for Integration and Interfaces
- 1 union FTE for operation and maintenance.
- The cost is exclusive of taxes, freight, and any applicable duties.

Table 15: NTCIP-compliant Signs with Commons Sign Control Order of Magnitude Costs

Vendor Costs

Hardware, Field	Quantity	Unit	Unit Cost	Extended Cost
Signs & Associated Control Unit/Comm	88	EA	$ 50,000	$ 4,400,000

Hardware, Spares	Quantity	Unit	Unit Cost	Extended Cost
			5%	$ 220,000

Software	Quantity	Unit	Unit Cost	Extended Cost
Central System Upgrades	1	LS	$ 300,000	$ 300,000
Interface with Existing Metro TDB & Systems	1	LS	$ 250,000	$ 250,000

Project Management	Quantity	Unit	Unit Cost	Extended Cost
Project Management Staff	1	LS	$ 150,000	$ 150,000
Design Reviews			15%	$ 45,000
Training			5%	$ 15,000
Acceptance Tests			10%	$ 30,000
Documentation			35%	$ 105,000
Performance Bond				$ 177,800

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	1	LS	$ 120,000	$ 120,000
Implementation Support	1	LS	$ 250,000	$ 250,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	1	EA	$ 100,000	$ 100,000
Testing	0.1	EA	$ 86,580	$ 8,658

Integration and interfaces	0.25	EA	$ 150,000	$ 37,500

			Capital
Subtotal Vendor Costs			$ 5,692,800
Subtotal Consultant Costs			$ 370,000
Contingency		10%	$ 606,280
Subtotal Agency Costs			$ 146,158
Total			**$ 6,815,000**

Support Costs	Quantity	Unit	Unit Cost	Extended Cost
Vendor Annual Cost for Post Warranty Hardware and software support			5%	$ 284,640
Agency Maintenance Costs	1	EA	$ 86,580	$ 86,580

Hardware Refresh Costs	Quantity	Unit	Unit Cost	Extended Cost
Equipment lifecycle replacement/upgrades			1%	$ 68,150

	10 Year O+M
Total	**$ 4,394,000**

5.1.12 Video Streaming for Bus and Rail (V.3 + V.4)

The following ROM costs for implementation of a Video Streaming System are based on the following assumptions:

- $5 per month per vehicle for cellular bandwidth.
- Cloud-based service for caching.
- 1360 buses will require a new network video recorder
- 0.1 FTE over 10 years for Metro project oversight.
- The cost is exclusive of taxes, freight, and any applicable duties.

Table 16: Video Streaming for Bus and Rail Order of Magnitude Costs

Vendor Cost: Hardware, Field	Quantity	Unit	Unit Cost	Extended Cost
Network Video Recorder	1360	EA	$ 4,500	$ 6,120,000
				Capital
	Total			**$ 6,120,000**

Support Costs	Quantity	Unit	Unit Cost	Extended Cost
Vendor Annual Cost for Post Warranty Hardware and software support			10%	$ 612,000
Cellular Costs	10	EA	$ 217,440	$ 2,174,400
Agency Maintenance Costs	10	EA	$ 15,000	$ 150,000
Caching	10	EA	$ 2,160	$ 21,600
				10 Year O+M
	Total			**$ 2,958,000**

5.1.13 SCADA Maintenance HMI (S.4)

The following ROM costs for implementation of a SCADA Maintenance HMI System are based on the following assumptions:

- Cost assumes existing ARINC software used.
- 0.2 FTE over 2 years for Metro project oversight.
- The cost is exclusive of taxes, freight, and any applicable duties.

Table 17: SCADA Maintenance HMI Order of Magnitude Costs

Vendor Costs

Hardware, Backend & Infrastructure	Quantity	Unit	Unit Cost	Extended Cost
SCADA Servers	4	EA	$ 1,939	$ 7,756
SCADA Client Workstations	10	EA	$ 1,779	$ 17,790

Hardware, Spares	Quantity	Unit	Unit Cost	Extended Cost
SCADA Servers	1	EA	$ 1,939	$ 1,939
SCADA Client Workstations	1	EA	$ 1,779	$ 1,779

Software	Quantity	Unit	Unit Cost	Extended Cost
Build Maintenance Oriented Graphics	1000	HRS	$ 100	$ 100,000

Project Management	Quantity	Unit	Unit Cost	Extended Cost
Project Management Staff	800	EA	$ 150	$ 120,000
Project Management Meetings	208	EA	$ 150	$ 31,200
Design Reviews	96	EA	$ 150	$ 14,400
Training	160	EA	$ 150	$ 24,000
Acceptance Tests	480	EA	$ 150	$ 72,000
Documentation	480	EA	$ 150	$ 72,000

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	200	EA	$ 150	$ 30,000
Implementation Support	100	EA	$ 150	$ 15,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	0.4	EA	$ 100,000	$ 40,000
Training	400	EA	$ 150	$ 60,000
Testing	200	EA	$ 150	$ 30,000
Contingency	200	EA	$ 150	$ 30,000

	Capital
Subtotal Vendor Costs	$ 462,864
Subtotal Consultant Costs	$ 45,000
Contingency	$ 15,000
Subtotal Agency Costs	$ 160,000
Total	**$ 683,000**

Support Costs	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
Vendor Annual Cost for Post Warranty Hardware and software support	10	EA	$ 10,000	$ 100,000

Hardware Refresh Costs	**Quantity**	**Unit**	**Unit Cost**	**Extended Cost**
Server replacements after 5 years	1	EA	$ 5,109	$ 5,109

	10 Year O+M
Total	**$ 105,000**

5.1.14 SCADA Message Gateway

The following ROM costs for implementation of a Message Gateway System are based on the assumption that there will be 0.2 FTE over 2 years for Metro project oversight. The cost is exclusive of taxes, freight, and any applicable duties.

Table 18: SCADA Message Gateway Order of Magnitude Costs

Vendor Costs

Hardware, Backend & Infrastructure	Quantity	Unit	Unit Cost	Extended Cost
Message Server	2	EA	$ 1,939	$ 3,878

Hardware, Spares	Quantity	Unit	Unit Cost	Extended Cost
SCADA Servers	1	EA	$ 1,939	$ 1,939

Software	Quantity	Unit	Unit Cost	Extended Cost
Build alarm database / Configure	400	HRS	$ 100	$ 40,000
Software License	2	EA	$ 2,700	$ 5,400

Project Management	Quantity	Unit	Unit Cost	Extended Cost
Project Management Staff	200	EA	$ 150	$ 30,000
Project Management Meetings	40	EA	$ 150	$ 6,000
Design Reviews	40	EA	$ 150	$ 6,000
Training	160	EA	$ 150	$ 24,000
Acceptance Tests	200	EA	$ 150	$ 30,000
Documentation	200	EA	$ 150	$ 30,000

Consultant Costs	Quantity	Unit	Unit Cost	Extended Cost
Engineering	200	EA	$ 150	$ 30,000
Implementation Support	100	EA	$ 150	$ 15,000

Agency Costs	Quantity	Unit	Unit Cost	Extended Cost
Project Oversight	0.4	EA	$ 100,000	$ 40,000
Training	400	EA	$ 150	$ 60,000
Testing	200	EA	$ 150	$ 30,000
Contingency	200	EA	$ 150	$ 30,000

	Capital
Subtotal Vendor Costs	$ 177,217
Subtotal Consultant Costs	$ 45,000
Contingency	$ 15,000
Subtotal Agency Costs	$ 160,000
Total	**$ 397,000**

Support Costs	Quantity	Unit	Unit Cost	Extended Cost
Vendor Annual Cost for Post Warranty Hardware and software support	1	EA	$ 405	$ 405

Hardware Refresh Costs	Quantity	Unit	Unit Cost	Extended Cost
Server replacements after 5 years	1	EA	$ 776	$ 776

	10 Year O+M
Total	**$ 12,000**

5.2 Bundling of Costs

There are some opportunities for cost reduction if certain projects are implemented concurrently. By running the voice and data communications for bus and the data communications and Improved Prediction for Rail projects in parallel with the ATMS II Bus and Rail project, there could be a reduction of $8.1 M in duplicated integration costs as well as the potential reduction of duplicate hardware. Other areas of potential cost reductions would be software development costs for Rail AVL, Arrival Prediction, Improved Service Alerting, and Traveler Information Aggregation if run in parallel with the ATMS II project.

6 Technology Trends and Impacts

> This section discusses technology trends that will impact the recommended projects and future projects. The technology trends will allow Metro to more easily and cost effectively implement future technologies.

When Metro commenced the deployment of its Advanced Transportation Management System (ATMS) computer aided dispatch/automated vehicle location (CAD/AVL) system, it was a state-of-the-art integration of Information Technology (IT), mobile communications, and on-board systems. CAD/AVL systems have continued to evolve since that time, however, and many things are technically feasible for the transit industry that were not options when the ATMS was deployed by Metro. Furthermore, some of these technology trends have been adopted from other uses and were not developed originally or specifically for transit use.

Many of the following central system and IT technology trends have already been adopted and are heavily utilized by Metro for both its bus and rail fleets since ATMS was first implemented including:

- Virtualized environments
- Cloud computing/services
- Software as a service
- Off-site server/application hosting
- Enhanced database interface tools
- Enhanced reporting and business intelligence (BI) tools

These trends will have substantial impact on the design of ATMS II, the on-board systems architecture, voice and data communications, and supporting systems that are recommended in this Strategic Plan. It is important to understand these trends as shifts and advances will likely impact the risks and costs associated with most of the recommended projects.

6.1 Looking to the Future

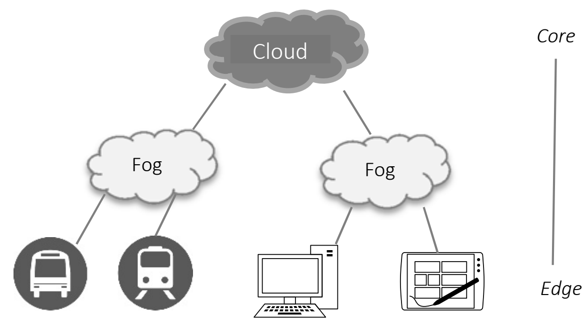
This Strategic Plan should be a living document and updated periodically—every five years or when Metro priorities and funding changes and to reflect new technology trends. Revisions to this Strategic Plan should incorporate findings from Metro's IT Strategic Plan and Metro's Strategic Plan for the entire agency, which are currently under development. Other regional ITS strategic plans should be considered at that time as well. In addition, updates to the Strategic Plan should account for ITS projects by Metro and other regional agencies that have been completed, in progress, or planned. IT systems should be updated/upgraded every five years and hosted and Software as a Service solutions should be considered at that time.

The following are some forward-looking trends that will influence the Strategic Plan as it is updated over the course of the next 15 years:

- More of an Internet of Things- (IoT-) type environment on the transit vehicle where devices and applications may become less centralized around the intelligent vehicle unit/vehicle logic unit (IVU/VLU). It is likely that either the MDT or the MGR would include functionality to support on-board data storage and supplemental processing needs, in addition to serving its primary function. An example would be a vehicle health monitoring (VHM) device that

would internally process and communicate key information to/from other devices, such as the MDT and the AVL devices. While this may seem a step back from the architecture centralized around a central IVU/VLU, it actually opens up transit vehicle architectures to transition and progress in a smoother and more logical fashion, as well as prevents agencies from being tied to a single integration vendor.

- Devices will be swappable and less dependent on make/model, so that, while there will still be variations in capabilities, it would not require a major integration effort to include new devices into the on-board architecture.
- At this point, it is anticipated that there will be much wider adoption of commercial industry standards. These might include AVL, fare payment, video, and display technologies.
- Commercial cellular, or in some cases public agency, data networks will be the primary mode of voice and data communications. Land mobile radio (LMR) solutions may be retained in some cases for fallback but are anticipated to phase out as they reach their lifecycle replacement timeframes.
- Edge device or "fog computing" comes into play with data processing being pushed to the edge of the on-board network environment and possibly involving multiple devices. For example, automated passenger counter (APC) data is currently heavily post-processed once downloaded from the vehicles. In the future, with improved sensors and the IoT-type approach, the processing will occur within the APC device itself with comparisons of passenger counts from enhanced video solutions for validation purposes.



- In addition to what is occurring largely from the IT and communications industries, there is a major push in North America and throughout parts of Asia and Europe for enhanced connected vehicle applications. While these originally focused on independent vehicle safety and vehicle-to-vehicle applications, the trends are expanding to include vehicle to roadside infrastructure applications. These include safety, signal control, controlled access, emissions monitoring, customer information, and many other applications that could be used by the transit industry.
- Increasingly, trends to support smart growth and sustainable development are including potential technology applications at multi-modal hubs. This includes tying together information from fleet systems to provide input and synergies with other modes at these hubs. Common methods of payment are increasingly being discussed, as well as more detailed wayfinding and customer-specific information. For example, a commuter express bus arriving at a mobility hub might customize information for alighting passengers and provide context-sensitive information they are likely to desire. While this area is still conceptual, it highlights the general trend of substantially increasing demands on fleet management systems for timely and accurate information.

Figure 8 below summarizes these trends in five basic categories with the following tables providing additional background associated with the individual elements labelled in the figure.

	On-Board Systems	Connected Vehicles	CAD/AVL Solutions	Voice Data Communications	Traveler Information
Current	O1 Ethernet/IP On-Board Mobile Gateway Router (MGR)	CV1 OEM Safety/Systems CV Pilots	CA1 Hosted Systems	VD1 Commercial Cellular Use (Legacy)	T1 Enhanced Arrival Prediction Engines GTFS & GTFS-RT Standardized Travel Info Interface
5 Years	O2 Open Platform IVUs O2 Shift to Off-Board Logic/ Functions with High Capacity Data	CV2 Transit V to I Applications Autonomous Bus Operations Pilots	CA2 Functions Shift to Back Office Focused Solutions On-Demand Services	VD2 LA - RICS Broader Buildout 5G	T2 Multimode/Anymode Mobile Apps Projected Displays (full daylight) Personalized Wayfinding
10 Years	O3 On-Board Device-to-Device "Edge Logic"	CV3 CV Based Prioritization of Traffic in Corridors (Pilots) Autonomous Bus Operations (Specific Facilities)	CA3 Larger Scale CAD/AVL SaaS Widespread Open Source Use	VD3 Large Scale Reduction of LMR Systems for Transit Use Flexible Data Switching Widespread FirstNet	T3 Complete Smartphone Penetration all Transit Users
15 Years	O4 Direct IoT Vehicle Devices to Cloud Service Widespread	CV4 Transit Prioritization in Corridor Throughput Autonomous Bus Operations (Regular Routes)	CA4 Shift to Predictive Schedules		T4 Trip Pattern Recognition/ Anticipation Intelligence for Transit

Figure 8: Anticipated Transit Technology Trends

ID	TREND DESCRIPTION
(O) On-Board Systems Trends	
O1 *Current*	• Ethernet/IP On-Board Mobile Gateway Router (MGR) – The expansion of IT-like network environments is already established with a widespread move in transit fleet systems to cellular data networks, on-board MGRs acting as communications/networking devices, and the increasing number of on-board devices that offer Ethernet connections and IP addressing schemes. This allows agencies to manage the on-board devices similar to how IT professionals manage office networks. It simplifies monitoring, maintenance, and upgrades, as well as significantly expands communications options and flexibility. It also allows for Wi-Fi connections between vehicles and backend systems to be optimized. Metro has already deployed pilots with this type of equipment, and has included it in its new bus procurement specifications. This is a starting point that can be built-upon as part of the new more open architecture that would be implemented as part of the Connected Fleet Vehicles & Facilities project being undertaken by Metro and the recommended ATMS II project. The

ID	TREND DESCRIPTION
(O) On-Board Systems Trends	
	push should be for all possible devices on-board to move to this Ethernet/IP type mobile network environment.
O2 *5 Years*	• Shift to Off-Board Logic Functions with High Capacity Data – The emergence and adoption of cost effective high capacity cellular data capabilities for transit agency use are changing the perspective on what functions need to occur on-board a vehicle versus those that can occur in the “cloud” or backend systems. For example, due to historic data communications limitations CAD/AVL systems generally focused schedule adherence and comparison functions on-board the vehicles that require significant scheduling data and processing functionality on-board. As commercial cellular data options have offered high-quality coverage and data throughput, the shift is starting to move more functions off the vehicle and into the back office applications environment. This trend will continue consistent with what is being seen in the rapid expansion of intelligent devices and the “Internet of Things” in the consumer electronics and logistics industries. • Open Platform Intelligent Vehicle Unit/Vehicle Logic Unit (IVU/VLU) – Historically CAD/AVL and transit on-board systems were highly proprietary including both the on-board software, hardware, and sometimes even the connections between devices. Due to changes in the broader electronics industry, widespread adoption of fleet management functions in logistics/trucking, and the increasing cost-competitiveness of electronic manufacturers, there is a broader range of hardened mobile computing devices that can operate and survive in bus or rail vehicle environments. The entry of automotive and heavy vehicle manufacturers into the broad adoption of more robust and upgradeable on-board electronics for information and entertainment means that more common and robust operating systems and development platforms for on-board exist today than ever before. Already interchangeable on-board computers exist that serve as IVU/VLUs for several CAD/AVL vendors, and Metro’s replacement for ATMS should be centered on a more open IVU/VLU platform that is not tied to a single vendor. The comparative example would be similar to a desktop computer which can be purchased from several different manufacturers and installed with software applications developed by a variety of vendors all running on a common operating system.
O3 *10 Years*	• On-Board Device to Device “Edge Logic” – A little further out is the pushing of the intelligence from the single IVU/VLU to the individual on-board devices. In an on-board networked environment, each of these devices would contain some intrinsic intelligence and would also be capable of sharing information to provide a more accurate and comprehensive set of data on the mobile transit environment. These types of devices and applications require the newer IoT type environment and will take several years to emerge in the transit marketplace. This means pushing for this in the on-board architecture for Metro was not realistic given the timeline for ATMS II.
O4 *15 Years*	• Direct IoT Vehicle Devices to Cloud Service Widespread – Ultimately, the traditional model of mobile vehicles communicating to a central CAD/AVL or related fleet management system will fade away. Widespread use of direct communications from mobile devices to applications residing in cloud services (e.g. Amazon Web Services, Microsoft Azure Cloud Services, etc.) will reach the transit industry on a widespread basis. This will allow transit agencies to deploy common mobile devices on vehicles, and establish direct communications from the vehicles to the “cloud” where any number of applications and functionalities could be running. The ability to easily expand fleet deployments, upgrade backend applications, and provide true “big data” analytics will be fully realized in this environment.

ID	TREND DESCRIPTION
(CV) Connected Vehicles	
CV1 *Current*	• Original Equipment Manufacturer (OEM) Safety Systems – Bus manufacturers are currently providing options for driver support and safety systems, such as forward collision warning, blind-spot vehicle detection, lane guidance support, etc. Most of these systems are selected for their ability to support driver safety, and some are deployed in special applications, such as freeway shoulder running or transit guideway operations. These systems are currently widely deployed in the consumer automotive and trucking industries to offer similar safety advantages. Some available features, such as adaptive cruise control, are not typically applicable for agencies such as Metro offering fixed route bus services. • Connected Vehicle (CV) Pilots – A number of connected vehicle pilots are being implemented as part of USDOT's national program efforts. These include a range of functions, including using CV for bus signal priority (BSP), supporting dynamic rideshare functions, improving customer information based on enhanced bus to roadside communications, etc. It should be noted only some of these applications rely on dedicated short range communications (DSRC) equipment, which operates in the 5.9 GHz band. There are also a number of Vehicle to Vehicle (V2V) applications in testing that provide an interconnected network of vehicles communicating with each other along a roadway corridor. As CV applications become more widespread in the general transportation environment, transit fleets will need to be part of this equation in order to make effective use of transit-specific as well as broader CV functionality.
CV2 *5 Years*	• Transit Vehicle to Infrastructure (V2I) Applications – As follow-up to the Connected Vehicle pilots, it can be anticipated that within the next five years more mainstream CV applications will appear for BSP, dynamic rideshare, and transit access and guideway control and monitoring. • Autonomous Bus Operations Pilots – Within five years several examples of autonomous bus operations pilots in guideways or semi-mixed operations should be in place. One example is the proposed autonomous bus operation pilot proposed for the recently awarded Columbus Smart City efforts.
CV3 *10 Years*	• Connected Vehicle Based Prioritization of Traffic in Corridors (Pilots) – This would be an early effort to demonstrate the ability to prioritize some types of traffic (e.g. transit and freight in some circumstances) in the overall equation of V2V vehicle networks and throughput along a corridor. Actual implementation of this would require a substantial set of private automobiles in a test corridor to also be CVs, but the early examples might dictate lane positions for vehicles based on the presence of buses (transit receiving priority). • Autonomous Bus Operations (Specific Facilities) - Early autonomous bus operations are likely to occur in guideways or dedicated bus lanes and facilities. They may also occur in environments that have been engineered to support autonomous bus operations in mixed flow operations. An example might be an autonomous circulator bus in a downtown environment running in marked bus lanes.
CV4 *15 Years*	• Transit Prioritization in Corridor Throughput – In the next 15 years, it is likely that CV applications will be much more common on the entire vehicle fleet (including private autos). This will create an environment where all the vehicles are communicating with one another and with specific roadside functions (e.g. signals, high occupancy vehicle (HOV) lane enforcement, etc.). This will allow for widespread implementation of algorithms and strategies focused on maximizing and promoting transit in the overall flow and throughput of a corridor. This will be most effective in fully autonomous environments. • Autonomous Bus Operations (Regular Routes) – The rapid progression of autonomous cars and trucks will eventually lead to more widespread use of autonomous buses. As driverless vehicles are already in test operations in real traffic conditions in several places in the US, autonomous bus operations in mixed traffic flow should be expected to expand from this period forward.

ID	TREND DESCRIPTION
(CA) CAD/AVL Solutions	
CA1 *Current*	• Hosted Solutions – Many transit agencies have been exploring variations of hosted solutions and environments, where they own the applications but they are actually managed and hosted by contracted vendors. These options in the past have been more advantageous for smaller fleets with more limited fleet system functionality, but this is starting to shift. Metro already uses hosted server services for some applications. These offer the advantage of allowing rapid adjustments to the computing power and capabilities available as the agency's needs may change. As another example, AC Transit is deploying its CAD/AVL core system functionality at a primary and secondary hosted data center.
CA2 *5 Years*	• Functions Shift to Back Office-Focused Solutions – As commercial cellular data options have offered high-quality coverage and data throughput, the shift is starting to move more functions off the vehicle and into the back office applications environment. It is much easier to deal with modifications and functional enhancements on the back office solution when the on-board architecture is simplified. As an example, with high-frequency reliable communications, schedule adherence calculations for individual vehicles could be made by back office solutions rather than on-board the vehicle. These approaches are begging to appear, particularly related to rail operations, schedule adherence, and prediction calculations. • On-Demand Services – Increasingly agencies are looking for their fleet management and CAD/AVL systems to support more flexible transit services. While some pilot projects and efforts have been undertaken, the ability and need to support demand driven transit services will increase. This could include options such as flex-routing and shifting interlining services and trippers to accommodate areas and platforms exhibiting unusually high passenger demands.
CA3 *10 Years*	• Large Scale CAD/AVL Software as a Service (SaaS) – Some transit agencies have moved from considering SaaS as a concept for supporting external elements of their fleet management system to including this consideration as a part of their evaluation of a CAD/AVL system replacement. While this has been common for smaller fleets, it is now emerging as a serious consideration for medium- to larger-sized transit fleets. Most vendors are not currently properly positioned to support major fleet management solutions as a SaaS, but this is expected to change with time. In about another 10 years, larger agencies may be able to approach a variety of fleet systems needs as a pure SaaS. • Widespread Open Source Use – Properly utilizing open source solutions for fleet applications has been historically difficult. Currently, a variety of transit information applications and coding resources reside in open source environments. TriMet is currently moving toward deploying an IoT Mobile Gateway that would support some open source applications for light rail use. The existing basis of open source software for transit customer information, arrival prediction, and fleet management solutions will slowly expand over time. If Metro maintains an open IVU/VLU platform and properly architectures the on-board environment, then they should be able to capitalize on some of these open source solutions for enhanced fleet functionality and customer information applications over time.
CA4 *15 Years*	• Shift to Predictive Schedules – Schedules are currently largely static and entered well in advance by skilled transit schedulers/planners. Some services operate on headways but are still subject to assumptions and estimations about the run times between time points. There are some rudimentary feedback processes to assist schedulers in refining timetables with current systems. This process will eventually become much more flexible and based on predictive modeling. Using much more frequent vehicle position updates and reporting to the CAD/AVL system and leveraging Business Intelligence and "Big Data" tools, systems will be able to supply accurate trends and seasonal variations in enough detail to automatically adjust the underlying transit schedules at set intervals with the input and guidance of skilled schedulers.

ID	TREND DESCRIPTION
(VD) Voice/Data Communications	
VD1 *Current*	• Commercial Cellular Use – With the current generation of CAD/AVL and fleet management systems, the use of commercial cellular data is widespread. This has been supported by lower cost data plans, commercial pooled data options, and aggressive pricing by competing cellular providers. Some recent examples of commercial cellular data use for CAD/AVL include RTD (Denver), AC Transit (Oakland), Foothill Transit, and many others. In addition, many transit agencies are moving to Voice over Internet Protocol (VoIP) solutions built on commercial cellular data networks.
VD2 *5 Years*	• LA-RICS Broader Build-out –Metro is currently reviewing LA-RICS coverage and services in a test effort with a single vehicle. The Communications Plan (part of this Strategic Plan) discusses comparing commercial cellular data and LA-RICS for costs, coverage, and performance. It can be assumed that over time, LA-RICS coverage may improve. Utilizing an on-board architecture with a flexible MGR will allow for Metro to determine which options best suit its needs over time and adjust as appropriate. • 5G Cellular – Currently most CAD/AVL and fleet systems on commercial cellular data operate on a 3G or 4G network. Within five years, 5G commercial cellular networks should become available, while 4G networks will likely remain active for some period beyond widespread 5G implementation. Again, the use of a flexible MGR will allow Metro to update cellular communications as needed.
VD3 *10 Years*	• Large Scale Reduction of LMR Systems for Transit Use – Many agencies that are moving to cellular data are considering VoIP solutions for voice. Most are retaining their current LMR voice radio systems (and sometimes data systems) as fallback or redundant solutions for the foreseeable future. Eventually these systems will reach their end of useful life and will require replacement or will be phased out. • Flexible Data Switching Widespread – MGRs allow for switching between various Wi-Fi and cellular data options depending on configuration, signal strength/related factors, and communications options. The switching process is still somewhat rudimentary and requires that data connections and communications be re-established resulting in lost or re-sent data. The flexibility of the MGRs to switch between a variety of communications solutions on the fly is expected to significantly improve within the next decade, further enhancing the communications flexibility and options available for fleet systems. • FirstNet (First Responder Network Authority) – FirstNet is a national effort to roll-out a broadband data network for emergency services. This is similar to a commercial cellular network, but it would be available exclusively to public safety agencies (transit is generally classified as public safety). It is possible LA-RICS could become the region's implementation of FirstNet.

ID	TREND DESCRIPTION
(T) Traveler Information	
T1 *Current*	• Enhanced Arrival Prediction Engines – Much improved bus and rail arrival prediction engines are becoming available as agencies substantially improve the frequency of their vehicle location updates and leverage newer cellular data communications. • GTFS & GTFS-realtime – GTFS is a widely deployed data format for transit schedule data across the nation, and its widespread use provides support for a wide range of customer information applications. Also, many agencies have or are rolling out real-time vehicle location and alerts updates in a GTFS-realtime format as they deploy or update their CAD/AVL systems. • Standardized Traveler Information Interface – Metro already provides a developer portal for access to Metro transit information to support the outside development of customer information applications. This is

ID	TREND DESCRIPTION
(T) Traveler Information	
	becoming a widespread practice for transit agencies, and the standardized interfaces and developer portal should be updated as ATMS II is deployed and provides enhanced information.
T2 *5 Years*	• Multi-Mode/Anymode Mobile Apps – Many smartphone applications provide links to separate apps for transit, auto, ridesharing, and related applications. However, they generally do not provide well integrated solutions for users that seamlessly allow movement between modes with scheduled and real-time information and status. Within the next few years this will significantly change as various modal service and information providers pair up and support each other's information in a more integrated fashion. • Projected Displays (full daylight) – Projected displays have the advantage of being able to provide more location specific data and improved wayfinding, but current units do not operate in full daylight. Improvements in this arena should reduce costs and improve daylight performance of these devices that could then be more widely utilized for transit and multi-modal applications. • Personalized Wayfinding – Wayfinding with smartphone applications is already widely available for a variety of purposes, but over the next few years this will become more closely tied to available displays and wayfinding indications located in the physical environment. For example, a customer might set a destination that includes using rail to reach a stop, and then routes them to a car-sharing location.
T3 *10 Years*	• Complete Smartphone Penetration of Transit Users – Statistics and surveys are showing that the younger generations are broadly adopting smartphone use regardless of income levels. Within the next ten years, inexpensive data plans and smartphones, combined with the natural transitions of social trends will mean the vast majority of transit users will have access to and use a smartphone. This has implications for current and future plans for providing fair and equitable customer information to the full range of transit users.
T4 *15 Years*	• Trip Pattern Recognition/Anticipation Intelligence for Transit Users – Already smartphone applications can anticipate typical trips you make on a frequent basis; however, these types of features are generally not multi-modal and do not readily tie into real-time transit information and service alerts. Instead of people having to subscribe to route alerts or using a variety of applications and services, the combined traveler information solution will anticipate a complex pattern of trip making; recognize traffic, transit, parking, and related conditions; and make appropriate recommendations, alerts, and adjustments.

6.1.1 Connected Vehicles

Figure 9 displays an anticipated timeline for the emergence of autonomous and connected vehicle functionality.

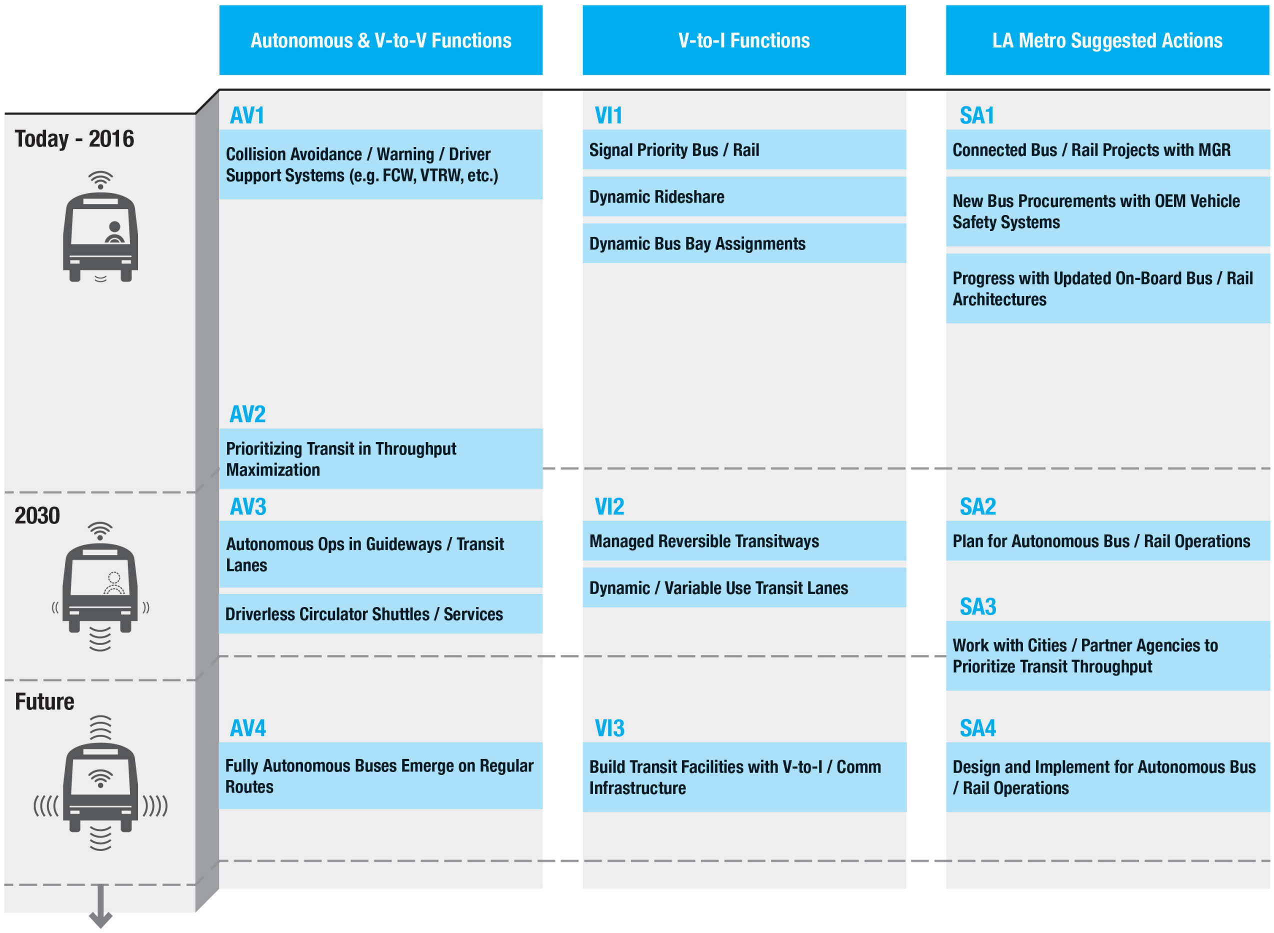


Figure 9: Anticipated Timeline for Transit Autonomous and Connected Vehicles

It should be noted that there are currently two distinct meanings for the "connected vehicle" terminology at Metro. Connected fleet vehicles, connected buses, or connected rail is used in discussing Metro fleet and communications systems to refer to the deployment of MGRs and cellular data communications on the fleet vehicles. More broadly, "connected vehicles" refers at a national and international level to discuss a series of concepts that represent a variety of communications, vehicle to vehicle (V2V) networking, and vehicle to infrastructure (V2I) connectivity and functionality. Autonomous vehicles are a specific set of functions that interrelate with connected vehicles and are focused on an increasing level of vehicle autonomy from direct driver input and control. Autonomous and connected vehicle functions are important to consider as they represent the following:

- Many connected vehicle functions have direct links to recommended fleet systems, particularly on-board equipment and components.
- Autonomous buses will play an increasing role in the future of transit operations beginning with enhanced driver safety systems and ultimately leading to increasing options for fully autonomous operations.
- Significant pending changes to the broader transportation and mobility environment will directly impact how transit operates and interrelates with other traffic and modes.

- There will be substantial federal and other funding opportunities for autonomous and connected vehicle applications that Metro will need to be involved in to maintain its competitiveness.
- Smart City set of technology and communications applications will be emerging over the next 15 years.

The following tables discuss major autonomous and connected vehicle trends illustrated in Figure 9 over the next fifteen years and beyond. The final table lists suggested actions for Metro.

ID	TREND DESCRIPTION
(AV1) Autonomous & Vehicle to Vehicle (V2V) Functions	
AV1 *Today*	• Collision Avoidance/Warning/Driver Safety Systems – As discussed in the table in the previous section above, a number of driver support and safety systems are available through current OEM/bus manufacturers. These systems can enhance operational safety and support the reduction of driver fatigue if properly implemented. Vehicle turning right warnings (VTRW) may be of particular interest for bus operations. In addition, pedestrian proximity and identification systems are widely available on a number of autos that will move into the transit industry in the near future. As buses carry a large number of passengers in a variety of configurations, it is important to consider the balance of active response (e.g. braking or corrective steering) that may be appropriate for individual bus service types.
AV2 *By 2025*	• Prioritizing Transit in Throughput Maximization – Once a broad set of vehicles is implemented with CV capabilities, it will be possible to implement "intelligent algorithms" that prioritize traffic by type and vehicle operating profiles. Early efforts in this area will commence with pilots and specific corridors that will be well suited to integration of autonomous and connected vehicles with CV equipped buses.
AV3 *by 2025-2030*	• Autonomous Operations in Guideways/Transit Lanes – Driver support and guidance systems are already in place to support bus operations in fixed guideways. By 2025 fully autonomous operations in high capacity transit guideways (buses and street operating rail – not just heavy rail) will emerge and become more commonplace. • Driverless Circulator Shuttles/Services – Initial operational pilot projects for driverless circulator services have already been announced and the technology exists to support these functions today. By 2025 the pilot projects will move into more widely available options for transit infrastructure and options.
AV4 *beyond 2030*	• Fully Autonomous Buses on Regular Routes – The individual technologies for autonomous operations of vehicle and buses exist today, but the policy and real-world challenges remain daunting. Ultimately fully autonomous operations for buses in regular service, on fixed routes, and mixed-flow traffic will become the norm.

ID	TREND DESCRIPTION
(VI) Vehicle to Infrastructure (V2I) Functions	
VI1 *Today*	• Signal Priority Bus/Rail – Many agencies are looking to signal prioritization as an "early win" for piloting CV functionality. These projects are somewhat similar to BSP efforts Metro has undertaken in the past but are more advanced and utilize CV functionality. Metro is undertaking a study to review the future for BSP that will provide more specific discussion of the potential applicability of CV applications to BSP. • Dynamic Ridershare – Transit would be tied into USDOT's concept for dynamic rideshare CV concepts, which would allow transit riders to pass anticipated arrival information to other parties (carpools, shared ride services, etc.).

ID	TREND DESCRIPTION
(VI) Vehicle to Infrastructure (V2I) Functions	
	• Integrated Corridor Management (ICM) – As part of a wider ICM concept, transit fleet systems information (such as on-board loads and next bus arriving) and related information (parking availability) will be provided to travelers along a congested corridor to promote the opportunity and advantages of using transit. This can be particularly applicable where transit has the advantage of transit/HOV lanes.
VI2 *2025-2030*	• Managed Reversible Transitways – Reversible transit lanes already exist and are controlled through signage and access barriers, but the application of autonomous and connected buses offers a much more intelligent and optimized approach to using shorter stretches of reversible lanes able to support both directions of travel throughout the day. This becomes more important in an increasingly constrained roadway environment. Utilizing fleet systems and CV functions for relative bus positions, current conditions, and historic trends, directions for reversible lane use can be automated and integrated directly with access controls/signals. • Dynamic/Variable Use Transit Lanes – Metro already makes widespread use of specially marked transit lanes exclusive to buses during particular periods or throughout the day. However, these lanes cannot easily adjust to special events, variable traffic patterns, etc. Dynamic lanes will utilize CV functions of both transit vehicles and private autos to maintain and control lanes assigned for transit use/priority.
VI3 *2030 & Beyond*	• Build Transit Facilities with V2I/Communications Infrastructure – By this period, the infrastructure elements of CV will be well established and all transit facilities will need to be built to support transit and related V2I functions.

ID	TREND DESCRIPTION
(SA) Metro Suggested Actions	
SA1 *Today*	• Connected Bus & Rail Projects with MGR – This is discussed in detail in the recommended on-board architecture and projects noted in this Plan. As with fleet systems, the MGR will offer flexible communications for a subset of Connected Vehicle functions. OEM safety functions tied directly to active vehicle guidance systems should remain independent of the MGR. • New Bus Procurements with OEM Vehicle Safety Systems – Within the next 10 years, buses and rail vehicles delivered with a variety of driver support and safety systems will be the norm. As fleet procurements occur over a period of time, Metro should consider what OEM vehicle safety and driver support systems would be appropriate for subsets of the vehicle fleets. For example, vehicles continuously operating in a freeway/commute environment may have different needs than those in continuous local street service. Procurements should allow for options for these systems that Metro can act upon at their discretion. • Progress with Updated On-Board Bus/Rail Architectures – As with the MGR discussion, the on-board architecture recommendations are discussed at length in this Plan. The architecture allows for connected vehicle and autonomous functionality in three areas: OEM vehicle systems tied to vehicle guidance and driver support, connected vehicle functions using communicated information from other on-board fleet systems to obtain data and fulfill functional needs, and specific connected vehicle functions operating on-board the vehicle within the IVU/VLU environment. As concepts for Connected Vehicles are rapidly evolving, it is likely that the specific CV applications will shift or change over time, but if Metro maintains a non-proprietary and open on-board network environment and IVU/VLU, it will greatly assist in supporting future CV applications.
SA2 *Today-2025*	• Plan for Autonomous Bus/Rail Operations – Autonomous operations are nothing new along fixed guideways, but the current and emerging set of autonomous vehicle functionality promises to be a game changer in terms of what is viable for autonomous operations in guideways, transit lanes with minimal traffic separation, and mixed traffic operations. Metro should be planning and considering these technical capabilities in infrastructure planning and design efforts. Autonomous operations offer to support higher frequency, precise stop positioning, and reduced operating costs over the ensuing two decades.

ID	TREND DESCRIPTION
(SA) Metro Suggested Actions	
SA3 *2020-Beyond*	• Work with Cities/Partner Agencies to Prioritize Transit Throughput – Metro already supports a variety of Bus Signal Priority (BSP) efforts, but CV applications and V2V networks of vehicles offer to enhance opportunities for significant advancements in the prioritization of types of traffic by corridor. Metro should be looking for pilot opportunities to promote transit as a logical and continued mode to prioritize along roadway and freeway corridors.
SA4 *2030-Beyond*	• Plan, Design, & Implement Autonomous Bus/Rail Operations – It is likely that by 2030 autonomous bus operations will reach into mixed traffic flow situations. Widespread private auto autonomous operations will occur before that time. Metro should be designing and implementing infrastructure, facilities, and operations that take this into consideration. It will fundamentally change the methods and approaches Metro currently uses over the next twenty years.

Appendix A – Concept of Operations

CONCEPT OF OPERATIONS: TRAIN PULLOUT

The following scenario illustrates the benefits of the systems to be implemented in the Strategic Plan and highlights the changes that will occur from current operations. Current operations that would be phased out by new technology are written in this color*, while* planned operations that would be added with new technology are written in this color and underlined.

TRAIN ASSIGNMENTS

Bob has been a supervisor for Rail Fleet Services at LA Metro's Blue Line Division 11 for three years. Each day, he walks the rail yard and writes the vehicle numbers and the lanes they are parked in on a piece of paper. Once completed, Bob faxes this information to Transportation at Division 11. Bob uses the Rail Yard module of the new Yard Management Tool to automatically document the lane location of each train in the yard and confirms the tool has logged the vehicle locations. Roman, the Transportation Operations Director, receives the fax from Bob, manually uses the Rail Yard module of the new Yard Management Tool which automatically assigns the train to the pullout times on the schedule. Roman lists the pullout assignments on a piece of paper and faxes the list to the ROC. The train pullout assignments are automatically sent to Hastus and ATMS II by the Yard Management Tool.

OPERATOR CHECK IN

Dan has been a LA Metro train operator for ten years and arrives at the Division 11 Blue Line yard to begin his work shift. Dan checks in using his badge to log into the Hastus Daily System on a workstation at the Yard Control Window. The Hastus System provides him with Operation Clearance Notices (OPS CLR), and prints out the pink letters. The Yard controller tells the operator where the operator's train is and writes down the operator assignments on a change sheet. Dan carries a printout of the train schedules and pink letters with him as he walks to the train. The Yard Controller checks to see if there are any notifications such as "see supervisor" or "complete transit safe form" for Dan that have been sent from ATMS II. The Yard Management Tool receives Dan's log in information from the Hastus System and automatically assigns Dan with a train ID and automatically sends the train ID and its location information to Hastus. The Hastus System provides Dan with the train ID and location of the train. Dan can access the train schedules and pink letters via the MDT for ATMS II. The operator train assignments are automatically sent to ATMS II by the Yard Management Tool.

PRE TRIP INSPECTION

Dan performs a pre-trip inspection of his assigned train and notes the results of the inspection on a Vehicle Condition Card. Dan logs into the MDT for ATMS II and enters the results of the pre-trip inspection. Once the pre-trip information has been entered, a pre-trip report that satisfies CHP is sent to the ATMS II backend via the Aruba WLAN system in a data message.

TRAIN DEFECT REPORTING

Dan discovers there is a defect with the train during the pre-trip inspection and uses the Blue Line Yard Channel of the voice radio system to call and inform Diana, the Blue Line Yard Controller, of the defect. ATMS II receives the pre-trip information from Dan's train and since a defect was noted, ATMS II sends a maintenance work order request to M3. Diana contacts Maintenance via telephone or via the Maintenance channel of the voice radio system to have Jeff, a vehicle technician repair the train. Jeff attempts to repair the defect but is unsuccessful and using the Maintenance channel of the voice radio system, notifies Diana. Jeff tags the train as defective. Jeff creates a work order in M3 for Dan's train and notes the defect using the laptop that is mounted in his maintenance vehicle.

TRAIN REPLACEMENT

Diana, using the Yard Management Tool, manually assigns a new train to Dan. Diana uses the new Yard Management Tool and submits a request for a new train. The new Yard Management Tool automatically identifies, locates, and assigns a new train to Dan.

PRE TRIP INSPECTION

Dan makes his way to his new train and performs a pre-trip inspection of his newly assigned train and notes the results of the inspection on a Vehicle Condition Card. The train passes the pre-trip inspection. Dan logs into the MDT for ATMS II and enters the results of the pre-trip inspection into the pre-trip inspection page of the MDT. Once the pre-trip information has been entered, a pre-trip report that satisfies CHP is sent to the ATMS II backend via the Aruba WLAN system. The onboard ATMS II system automatically commands the train's destination signs to display the correct destination and commands the Onboard Passenger Information system to display the correct information based on Dan's log-in information.

LATE TRAIN PULLOUT

Since Dan has exceeded his 25 minute window for his pre-trip, he will not pullout at his normally scheduled time. Diana uses the Blue Mainline channel of the voice radio system to notify Bill, the Blue Line Mainline Controller who is located at the ROC of the late pullout. Bill uses his ATMS II workstation to review the operator assignments and train pullout assignments. To compensate for Dan's late pullout, Bill uses his ATMS II workstation and adjusts the Blue Line schedule by bumping the line or using a gap train at the terminal. ATMS II sends the adjustments to Hastus and to the rail prediction engine.

There were no defects discovered and so Dan calls Diana via the Blue Line Yard channel of the voice radio system to request authorization to move the train to the yard limits. Diana grants authorization and when Dan reaches the yard limits, Dan uses the Blue Mainline channel of the voice radio system to request authorization to go into service from Bill, the Blue Line Mainline Controller who is located at the ROC. Bill verbally provides authorization. Bill verbally provides all new updates to the OPS CLR and Dan repeats them verbatim. All notices, entered into ATMS II by Bill and other Mainline Controllers are also sent by ATMS II to the MDT via the Aruba WLAN system and Dan reads each notice. Using the MDT, Dan sends an acknowledgement for each notice to Bill via the Aruba WLAN system. Bill looks at his ATMS II workstation display and notes that Dan has acknowledged all notices and therefore does not verbalize them to Dan. Bill manually logs the pullout of Dan's train in a Train summary report. The new Yard Management tool tracks the movements of Dan's train and automatically logs and sends the yard pullout data to ATMS II.

VEHICLE LOCATION AND STATUS TRACKING

The SCADA system tracks the location of Dan's train and all other trains on the Blue as they proceed on their trips and displays their locations on the SCADA workstation displays. The NextBus system receives the train location information from SCADA and Hastus, calculates the train's arrival at the Blue Line stops, and provides this information to Trip Master. The Onboard ATMS II system collects vehicle location data from the GPS receiver and sends position updates every 30 seconds to the ATMS II backend via the cellular data network. ATMS II collects vehicle location data provided by beacons installed at key locations on the tracks and merges this information with the GPS data from the train, and the train tracking location information from SCADA to calculate the location of Dan's train and display it on a map display on the ATMS II workstation for Bill and the other controllers that are managing the Blue Line. The rail prediction engine uses the train locations provided by ATMS II and information from SCADA and Hastus to predict the train's arrival at the Blue Line stops and provides this information to the Enhanced Multi-modal Real-time Aggregation System, and Metro's GTFS-realtime Feed which provides traveler information to Metro's passengers via Nextrip, RIITS, and Metro's smartphone app and website.

PASSENGER INFORMATION

Sheila is a long time Metro passenger who is commuting to work on the Blue Line. She uses her smartphone to access Metro's smartphone app or website, which provides her with the predicted arrival time of the next train. She boards Dan's train at the Willow station. While onboard, Sheila receives passenger information, general service announcements, and infotainment from the LCD monitors and the PA system. When the train is approaching a station, Dan presses a button to trigger the next stop announcement on the PA system and LCD monitors. The Onboard ATMS II system provides Sheila with real-time passenger information via the LCD displays and PA system. The Onboard ATMS II system calculates the position of Dan's train and automatically announces the upcoming stations on the onboard LCD passenger information display and on the PA system. The LCD display alternates between providing a list of the upcoming stations and general service announcements and possibly location-based advertising. Sheila can also access the internet using her smartphone using the passenger Wi-Fi system provided by Metro.

DATA MESSAGING

Dan receives voice announcements from the Bill and other Blue Line controllers from the Blue Line using the Blue Line mainline channel of the voice radio system and repeats them verbatim back to the controllers. Dan also receives text message notices from Bill and other Blue Line controllers via the cellular data network on his MDT. Dan reads the notices and sends acknowledgements using the MDT to Bill and the other Blue Line controllers via the cellular data network.

END OF LINE LOGOFF

When Dan's train reaches the end of the line, Dan logs off the MDT and departs from the train and takes his break. Frank, a fallback operator boards the train, logs onto the MDT and receives any updates to OPS CLR on the MDT and sends an acknowledgement to the Blue Line controllers via the cellular data network.

CONCEPT OF OPERATIONS: BUS ROLLOUT

The following scenario illustrates the benefits of the systems to be implemented in the Strategic Plan and highlights the changes that will occur from current operations. Current operations that would be phased out by new technology are written like this*, while* planned operations that would be added with new technology are written in this color and underlined.

BUS ASSIGNMENTS

Bob has been the lead ERS at LA Metro's Division 10 for three years. Each day, after buses return from service they are cleaned, refueled, and parked. Bob walks the yard and notes the parking location and type of each bus on a piece of paper called a Yard Sheet. Bob returns to his office where he uses his desktop PC to log into HASTUS Daily to assign buses to work assignments based on the rollout position of the bus. Bus operators that are working each assignment are also assigned to the bus and this information is stored in HASTUS Daily. Bob uses the Bus Yard module of the new Yard Management Tool that automatically locates the buses in the yard, and assigns operators and work assignments to each bus based on operator and work assignment data that is automatically imported from HASTUS Daily. The bus assignments for the operators are automatically sent from the Yard Management Tool to HASTUS Daily.

OPERATOR CHECK IN

Danielle has been an operator for Metro for seven years. She arrives at the Division 10 yard and checks in with Carlos, the Window TOS. As the Window TOS, Carlos is responsible for checking in the operators. He greets Danielle and Danielle uses her badge to authenticate herself on the workstation located at the check-in window into the HASTUS Daily system and receives her bus assignment and location, work assignment, and paddle printout. Carlos checks to see if there are any notifications such as "see supervisor" or "complete transit safe form" for Danielle that have been sent to him from ATMS II. Danielle can access the paddle and pink letters via the MDT for ATMS II.

PRE TRIP INSPECTION

Danielle knows she has thirteen minutes to find her assigned bus, turn it on, power up the ATMS MDT and the farebox, and log onto the farebox or ATMS MDT with her badge. She performs a pre-trip inspection and notes the results on a Maintenance 9 card and notices that there is a brake issue. She enters the pre-trip inspection results on the pre-trip inspection page of the MDT. Once completed, the pre-trip inspection report is sent to the ATMS II backend via the upgraded Aruba WLAN in the yard.

BUS DEFECT REPORTING

ATMS II receives the pre-trip information from Danielle's bus and since a defect was noted, ATMS sends a maintenance work order request to M3. Since the report indicates there is a mechanical defect, a service message is automatically routed to the ATMS II workstation in maintenance area. Jeff, the Yard TOS, receives notification via WLAN of the defect on Danielle's bus on his tablet or laptop while he is in his vehicle or in his office. Danielle finds Walter, a mechanic at Danielle's division and notifies him of the bus defect but Walter says he is backed up and that it will take him more than hour to get to Danielle's bus to fix the defect. Walter creates a work order in M3 for Danielle's bus and notes the defect using the laptop that is mounted in his maintenance truck.

BUS REPLACEMENT

Danielle finds Jeff, the Yard TOS on duty. Jeff manually selects another bus for Danielle to use Jeff uses the new Yard Management Tool to automatically identifies, locates, and assigns a new bus to Danielle. Using his tablet or laptop with a wireless connection to M3, Jeff makes a note about the defective bus in M3 and enters Danielle's new bus assignment into HASTUS Daily the Bus Yard Tool which sends Danielle's new bus assignment to HASTUS Daily.

PRE TRIP INSPECTION

Danielle makes her way to her new bus, which passes the pre-trip inspection perfectly. She fills out the Maintenance 9 card. Danielle logs into the MDT and enters the results of the pre-trip inspection into the pre-trip inspection page of the MDT. She places the Maintenance 9 card in the bus windshield for review at the CHP's discretion. Once the pre-trip information has been entered, a pre-trip report that satisfies CHP is sent to the ATMS II backend via the Arruba WLAN system in a data message. The onboard ATMS II system automatically commands the bus's destination signs to display the correct line and destination and commands the Onboard Passenger Information system to display the correct information based on Danielle's log-in information.

YARD PULLOUT

As Danielle pulls out of the yard, Jeff, the Yard TOS logs her pullout on a piece of paper as the bus leaves the Division 10 yard the Bus Yard tool automatically logs the departure of Danielle's bus and stores the information in the new ATMS database.

VEHICLE LOCATION AND STATUS TRACKING

Danielle's bus receives GPS coordinates from the GPS satellites and transmits its location information to the ATMS backend via the ATMS data radio system every 3 minutes ATMS II backend via Metro's fleet cellular data network every 30 seconds. When Antonio sees the status of Danielle's bus on the ATMS II displays at his workstation, he can see the location of her bus, real-time passenger count, and its Deadhead status. ATMS II provides the real-time location of Danielle's bus to NextBus, which provides real-time location information and predictions and predictions for Danielle's bus to the Enhanced Multi-modal Real-time Aggregation System, and Metro's GTFS-realtime feed to Nextrip, RIITS, and Metro's smartphone app and website. When Danielle's bus reaches the first timepoint, the status of Danielle's bus changes on to, "Service."

FARE COLLECTION

Sara is a long time Metro passenger who is commuting to work on via the Metro bus system. She uses her smartphone to access Metro's app that provides her with the predicted arrival time of the next three bus arrival times at her stop. While waiting for the bus, Sara uses the Metro website or app to add value to her TAP card. Once the value has been added, the UFS system sends an update to all of the fareboxes via the yard WLAN system when the buses return to the bus yard immediately via Metro's fleet cellular data network. Danielle's bus arrives and Sara touches the farebox's validator with her TAP card as she boards the bus. Danielle uses the farebox's operator control unit ATMS II MDT to perform farebox functions and the operator control unit ATMS II MDT displays the remaining value left on Sara's TAP card.

PASSENGER INFORMATION

While onboard, Sara receives passenger information and infotainment from the PA system and LED signs LCD monitors. The LED signs display next stop information, stop requested notifications, and general service announcements. The LCD display alternates between providing a list of the upcoming stops, stop requested notifications, general service announcements and possibly location based advertising. Sara can also access the internet using her smartphone using the passenger Wi-Fi system provided by Metro.

CONCEPT OF OPERATIONS: TRAIN EMERGENCY

The following scenario illustrates the benefits of the systems to be implemented in the Strategic Plan and highlights the changes that will occur from current operations. Current operations that would be phased out by new technology are written like this*, while* planned operations that would be added with new technology are written in this color and underlined.

NORMAL OPERATION

David has been an LA Metro train operator for four years. Most of his operator experience has been running trains on the Gold line, but he has recently been transferred to the newly expanded Expo Line, which he is operating when today's incident occurs. David leaves the downtown Santa Monica station and heads eastbound on tracks that run along Colorado Avenue in Santa Monica. The SCADA system provides approximate location information for David's train by indicating which train track the train is on. David's train receives GPS coordinates from the GPS satellites and transmits its location and passenger count to the ATMS II backend via the Metro fleet cellular data network every 30 seconds. ATMS II tracks the location of David's train by merging GPS data with SCADA data and displays its location and passenger count on a street map.

COLLISION AND EMERGENCY NOTIFICATION

Rodrigo, a roofing contractor, is late for an appointment and he is driving south on 11th street. At the Colorado/11th Street at-grade crossing, Rodrigo runs through a red light, hoping to cross Colorado before the oncoming train. David sees Rodrigo's truck crossing in front of him and applies the LRV's brakes but it is not enough to avoid a collision. The front left corner of his train smashes into the right rear corner of Rodrigo's truck. David brings the train to a full stop and using the Expo Line channel of the Icom voice radio system calls the mainline controller for the Expo line at the ROC to respond to a T73 (train vs. auto). David presses an emergency button on the ATMS II MDT to tag the video data before and after the collision so the data can be more easily retrieved and will not be overwritten. During the emergency event, the onboard ATMS II system streams the onboard video images to the cloud via the Metro fleet cellular data network where it is temporarily cached so the video can be viewed by Metro staff. The collision triggers an event notification on the SmartDrive system, which uploads data regarding the collision via the SmartDrive cellular link the Metro fleet cellular data network to SmartDrive for storage and analysis.

Angela is the mainline controller for the Expo line and answers David's the radio call. David provides Angela with his location, direction and severity of the damage. Angela confirms David's location by looking at his train location as indicated on her ATMS II map display. David describes what happened. Angela activates the video streaming function to view the current situation onboard the train. She is able to view images from each camera.

Since David's train is stopped due to the collision, Angela sees on her SCADA workstation that the train location on remains on one of the tracks but it does not indicate that the train is stationary. Angela can see from the street map on her ATMS II workstation that David's train is stationary. ATMS II indicates the train has stopped and adjusts the predicted arrival time for David's train. Using her ATMS II workstation, Angela places David's train in "inactive status," causing ATMS II to remove all predictions for the train and to forward this information to the multi modal real-time aggregation system, which then provides the information to Nextrip.

FIELD SUPERVISOR SUPPORT

After using her ATMS II map display to determine who is closest to the incident, Angela issues a call on the Expo line channel of the Icom voice radio system for any field supervisor for Mark, a field supervisor, who she can see on the map is already nearby, to head to the scene. Using her ATMS II workstation, Angela types a message with instructions to manage the incident and sends it to Mark's ATMS portable laptop or tablet via Metro's fleet cellular data network. Mark receives the message on his ATMS portable

laptop or tablet and sends an acknowledgement response via Metro's fleet cellular data network. Angela sees the acknowledgement response on her ATMS II workstation. Angela also calls 911 using her telephone handset and reports the accident to the police.

Mark arrives at the scene and sets up a command outpost as the on-scene coordinator. Mark provides updates to the ROC using his Icom voice radio. Mark also uses his cell phone to coordinate with other agencies as needed. Emergency medical services personnel and Santa Monica police quickly arrive on the scene to attend to the truck driver and the train passengers. While EMS personnel talk to passengers, and the police talk to Rodrigo and David, Mark examines the train thoroughly. Mark uses the Expo Line channel of the Icom voice radio system to call Tim, the Expo Line yard controller to create a shell for an accident report in Transit Safe. Mark takes pictures and writes notes to document the incident. When Mark has finished his work at the scene of the accident, he must drive to the rail yard to download the pictures he took and file a 172 report on a desktop PC running the Transit Safe software. Angela also files an accident report, but she files hers in M3. Angela creates an incident form for the accident in ATMS II and ATMS II automatically identifies potential spelling errors. Mark takes pictures and logs notes using his ATMS portable laptop or tablet. While on scene, Mark creates a shell for an accident report in Transit Safe and uploads his 172 report using the Metro fleet cellular data network to connect to Transit Safe. Mark also submits updates to the ATMS incident form created by Angela using his ATMS portable laptop or tablet.

Mark uses his portable to advise Angela that the media has arrived on scene using Expo line channel of the Icom voice radio system. Angela calls Media Relations to advise them of the situation. When approached by media folks, Mark refers them to contact Media Relations for information.

BUS BRIDGE

Mark realizes that a bus bridge will be needed while the incident is resolved and informs Angela. Angela calls the BOC to request a bus bridge until the incident is closed and creates a bus bridge incident in ATMS II. The bus bridge process described in the BUS BRIDGE SCENARIO occurs.

RESUMPTION OF SERVICE

Mark issues Courtesy Cards to the passengers and collects the cards that are completed at the scene. Mark uploads images of the completed courtesy cards when he returns to the rail yard while on scene using the ATMS portable laptop or tablet. Mark remains on scene as the coordinator until resolution of the incident. If the incident takes more than 12 hours to be concluded, another field supervisor will be sent to the scene to relieve Mark.

Since the damage to the train appears minor and is mostly cosmetic, Mark uses his portable to advise Angela that David's train should be placed back in service now that the police have concluded their investigation. Using her ATMS II workstation, Angela ends the bus bridge event and places David's train back in "active status," causing ATMS II to resume providing predictions for the train and to forward this information to the multi modal real-time aggregation system, which then provides the information to Nextrip. ATMS II automatically sends an alert removal notification of the bus bridge to the Enhanced Multi-modal Real-time Alerts System which removes the alert from the appropriate systems including electronic rail station and bus stop signs.

TRANSIT SAFE REPORT

Angela calls Manny, the window dispatcher for the Expo Line Division 14 and tells him ATMS II automatically sends an alert to Manny, the window dispatcher for Division 14 and to Hastus that David needs to complete a Trans 30 report when he returns to the division.

Video from the onboard video security system is reviewed when the train returns to the rail yard and the hard drive from the DVR is removed and downloaded. SmartDrive data from the collision is also reviewed. Additional courtesy cards that have been mailed in are sent to the Expo Division and where they are reviewed and entered into the Transit Safe report.

Manny tells David to complete a Trans 30 report on a desktop PC running the Transit Safe software when he returns to Division 14. David also receives an alert to complete the Trans 30 report when he checks in at a Hastus workstation.

CONCEPT OF OPERATIONS: BUS EMERGENCY SAS

The following scenario illustrates the benefits of the systems to be implemented in the Strategic Plan and highlights the changes that will occur from current operation. Current operations that would be phased out by new technology are written like this*, while* planned operations that would be added with new technology are written in this color and underlined.

NORMAL OPERATION

Don has been an LA Metro bus operator for ten years and is now based at Division 13. Don is driving an articulated bus for the 720 line eastbound on Wilshire Boulevard in Santa Monica towards downtown Los Angeles. Don's bus receives GPS coordinates from the GPS satellites and transmits its location and passenger count to the ATMS backend via the ATMS data radio system every 3 minutes to the ATMS II backend via the Metro fleet cellular data network every 30 seconds. ATMS tracks the location of Don's bus and displays its location and passenger count on an AVL map. Don's vehicle location is automatically sent from ATMS to the TDB and to NextBus the multi modal real-time aggregation system which provides the information to Nextrip.

FALSE ALARM

As the bus crosses Lincoln Boulevard, Don's bus inadvertently activates a silent alarm (SAS) when a car merges into Don's lane and Don has to brake suddenly. The SAS message is sent by the onboard ATMS II system to the BOC via the ATMS data radio system via Metro's fleet cellular data network. Don can see a subtle indicator from the ATMS MDT that the SAS alarm has been sent to the BOC. The SAS activation also causes the onboard video security system to record at a higher frame rate and to tag the video data; allowing it to be more easily retrieved and preventing it from being overwritten. All of the controllers in the BOC see the SAS on their ATMS displays and hear an audio alarm as well. A window pops up on the map display that shows the location of Don's bus. While an SAS is active, Don's bus sends location updates to the BOC every 15 seconds via the ATMS data radio system via Metro's fleet cellular data network. Ann, the controller who is assigned to the 720 line, opens an incident for the SAS at her workstation, which causes the audio alarms on all of the other controllers' workstations to stop. When Ann opens the incident form, the onboard ATMS system for Don's bus automatically begins to broadcast audio from the covert microphone via the ATMS voice radio system via the VoIP system and streams the onboard video to the cloud via Metro's fleet cellular data network. Don sees a subtle indicator provided by ATMS MDT that a covert microphone and streaming video have has been activated. Paul is the Sheriff dispatcher who is on duty at the BOC. He sees the SAS on his ATMS workstation and hears the audio from the covert microphone and sees streaming video from the bus. After listening to the covert mic for a few minutes, Paul does not hear anything that would indicate there is an emergency situation. Paul and Ann confer and due to the uncertainty, Paul has to dispatch a Sheriff to the bus using his Sheriff dispatch console. The dispatched Sheriff reaches the bus and determines there is a false alarm. Paul and Ann are able to selectively view the video from each of the cameras and listen to the audio from the selected camera. They determine there is a false alarm. Ann overrides the SAS. The ATMS MDT reverts to its normal display and the bus location updating to the BOC returns to the standard rate of once every 3 minutes 30 seconds. Ann sends a pickup message to the ATMS MDT on Don's bus via the ATMS data radio system via Metro's fleet cellular data network. Don sees the message and pushes the Press to Talk on the handset and begins to talk to Ann via the via the ATMS voice radio system via the VoIP system. Ann confirms with Don that the SAS was a false alarm. After Don confirms the false SAS, Ann asks Don to pull over and see if the headsign is displaying "Call Police." Don pulls over and sees that the headsign is displaying the correct route and destination. Don relays this to Ann and she instructs Don to continue his service.

SAS ALARM

As Don's bus continues eastward on Wilshire Blvd, a passenger boards at the Westwood stop and begins to argue with Don because he doesn't have enough money on his TAP card or cash to pay for the fare. The passenger states that additional funds were added to his TAP card so there is a mistake with his TAP account. Since the fareboxes are connected to the UFS backend via Metro's fleet data network to get real-time updates to TAP accounts, Don tells shows the TAP balance on the passenger's card via the ATMS II MDT display that also serves as the

control head for the farebox. Don asks the passenger to step off the bus but the passenger refuses and begins to verbally assault Don. Don presses the SAS button. The SAS message is sent by the onboard ATMS system to the BOC via the ATMS data radio system via Metro's fleet cellular data network. Don can see a subtle indicator from the ATMS MDT that the SAS alarm has been sent to the BOC. The SAS activation also causes the onboard video security system to record at a higher frame rate and to tag the video data; allowing it to be more easily retrieved and preventing it from being overwritten. All of the controllers in the BOC see the SAS on their ATMS displays and hear an audio alarm. A window pops up on the map display that shows the location of Don's bus. While an SAS is active, Don's bus sends location updates to the BOC every 15 seconds via the ATMS data radio system via Metro's fleet cellular data network. Ann sees the new SAS from Don's bus and opens an incident form for the new SAS at her workstation, which causes the audio alarms on the all of the other controllers' workstations to stop. When Ann opens the ATMS incident form, the onboard ATMS system for Don's bus automatically begins to broadcast audio from the covert microphone via the ATMS voice radio system via the VoIP system and streams the onboard video to the cloud via Metro's fleet cellular data network. Don sees a subtle indicator provided by ATMS MDT that a covert microphone and streaming video have has been activated. Paul is the Sheriff dispatcher who is on duty at the BOC. He sees the SAS on his ATMS workstation and hears the audio from the covert microphone and sees streaming video from the bus. Paul and Ann are able to selectively view the video from each of the cameras and listen to the audio from the selected camera. Paul and Ann determine that this is a true SAS and Paul dispatches a Sheriff to Don's bus. Ann documents the details of the SAS in the ATMS incident form and ATMS II automatically identifies potential spelling errors. Ann uses her ATMS workstation to create an All Call broadcast to all road supervisors on the Supervisor talk group of the ATMS voice radio system VoIP system. The All Call broadcast message causes the portables for the Road Supervisors to beep three times, which alerts the supervisors to write down the information from the Code 1 call. Ann sends the information in a text message to the laptop portable laptop or tablet in the Road Supervisor vehicles via the cellular data network. Tom and Al, the first two road supervisors to respond, head to Don's bus. They use their laptop portable laptop or tablet to acknowledge Ann's message and track the location of Don's bus. The road supervisors follow Don's bus and observe what is occurring on the bus, but do not attempt to board the bus, as they wait for the Sheriff to arrive. The Sheriff reaches Don's bus and pulls in front of it, causing the bus to stop. The sheriff uses a bull horn and orders the unruly passenger to leave the bus. The unruly passenger refuses and states he is armed. Don opens the front and rear doors and all of the passengers and Don quickly leave the bus leaving the unruly passenger as the only one onboard. A tense standoff ensues. Tom uses his portable to call Ann via the ATMS voice radio system via the VoIP system and advise her of the situation. Ann calls 911 for a police support. Ann and the Paul continue to listen to the covert audio listen to the covert audio and watch the streaming video from the bus on their ATMS workstations in the BOC and share this information with law enforcement.

As the standoff continues, the police close off Wilshire Boulevard in the vicinity of the bus. Tom uses his portable to advise Ann that the media has arrived on scene via the ATMS voice radio system via the VoIP system. Ann calls Media Relations to advise them of the situation. When approached by media folks, Tom refers them to contact Media Relations for information.

DETOUR

Tom uses his portable to advise Ann of the street closure via the ATMS voice radio system via the VoIP system. Ann uses her ATMS workstation to create a detour around the road closure for the 720 line and sends a detour message to all operators that are currently operating or are scheduled to operate on the 720 line via the ATMS data radio system via Metro's fleet cellular data network. Ann uses an Everbridge workstation to type an alert message regarding the detour and notifies social media of the detour ATMS II automatically sends an alert notification to the Enhanced Multi-modal Real-time Alerts System which disseminates the alert to the appropriate systems including electronic bus stop signs. Jack is an operator on the 720 line and sees the detour message on his MDT. The MDT displays a map of the detour route. Ann uses her ATMS II workstation to send a detour notification message that is displayed on the LCD monitors on all buses via Metro's fleet cellular data network. Ann uses her ATMS II workstation to make a voice announcement of the detour on the PA systems for all 720 line buses via the VoIP system.

ATMS tracks the location of Jack's bus and other buses on the 720. Since a detour has been established, the buses do not indicate an off-route status while on the detour. ATMS II adjusts the arrival predictions based on the additional distance the buses must travel due to the detour and removes arrival predictions for stops that are bypassed as a result of the detour. ATMS II removes the display of time of arrival predictions on electronic signs at the bus stops that are bypassed.
Since Don's bus is stopped due to the emergency situation, ATMS first changes the bus' status to late and Nextrip adjusts the predicted arrival time for Don's bus. ATMS then changes the bus' status to a no show when the bus fails to make two time point encounters and forwards the bus' location information to NextBus which provides the information to Nextrip. Using her ATMS II workstation, Ann places Don's bus in "inactive status," causing ATMS II to remove all predictions for the bus and to forward this information to the multi modal real-time aggregation system, which then provides the information to Nextrip.

RESOLUTION OF EMERGENCY

The unruly passenger finally leaves the bus and is taken into custody without further incident. Tom takes notes for a report to be filed in Transit Safe for this incident when he returns to his division uses his portable laptop or tablet to complete the Transit Safe report and submits it via Metro's fleet cellular data network. Tom uses his portable to advise Ann of the emergency resolution via the ATMS voice radio system via the VoIP system. Ann uses her ATMS workstation and overrides the SAS and places Don's bus back in "active status." The ATMS MDT reverts to its normal display and the bus location updating to the BOC returns to the standard rate of once every 3 minutes 30 seconds.

REMOVAL OF DETOUR

Now that the situation has been resolved, the police re-open Wilshire Blvd. Ann uses her ATMS workstation to cancel the detour she had created previously and sends a cancel detour message to all operators that are currently operating or are scheduled to operate on the 720 line via the ATMS data radio system via Metro's fleet cellular data network. Ann uses one of the Everbridge workstations to cancel the alert message regarding the detour and notifies social media of the detour cancellation ATMS II automatically sends an alert removal notification to the Enhanced Multi-modal Real-time Alerts System which removes the alert from the appropriate systems including electronic bus stop signs. Jack is an operator on the 720 line and sees the detour cancellation message on his MDT. Jack's MDT no longer displays a map of the detour route. Ann uses her ATMS workstation to remove the detour notification message that are being displayed on the LCD monitors on all buses via Metro's fleet cellular data network. Ann uses her ATMS workstation to makes a voice announcement that the detour has been canceled on the PA systems for all 720 line buses via the VoIP system. ATMS II re-adjusts the arrival predictions so additional time is no longer added for the extra distance buses were traveling on the detour and reinstates arrival predictions for stops that had been bypassed as a result of the detour. ATMS II reinstates the display of time of arrival predictions on electronic signs at the bus stops that had been bypassed.

RESUMPTION OF SERVICE

Don returns to his bus. Ann sends a pickup message to the ATMS MDT on Don's bus via the ATMS data radio system via Metro's fleet cellular data network. Don sees the message and pushes the Press-to-Talk on the handset and begins to talk to Ann via the ATMS voice radio system VoIP system. Ann asks Don to check the headsign display. Don checks the headsign and tells her the display says "Call Police". Ann tells Don to have one of the road supervisors reset the headsign by shutting off the bus' battery by (using maintenance codes) on the ATMS MDT. Once the Tom and Al have concluded their investigations and the headsign has been reset, Don continues his work assignment. ATMS resumes tracking the location of Don's bus and displays its location and passenger count on an AVL map. Don's vehicle location is automatically sent from ATMS to the TDB and to NextBus the multi modal real-time aggregation system which provides the information to Nextrip.

TRANSIT SAFE REPORT

Ann calls the Mark, the window dispatcher for Division 13 and tells him ATMS II automatically sends an alert to the Mark, the window dispatcher for Division 13 and to Hastus that Don needs to file a report in Transit Safe when he returns to the division.

CONCEPT OF OPERATIONS: BUS BRIDGE

The following scenario illustrates the benefits of the systems to be implemented in the Strategic Plan and highlights the changes that will occur from current operation. Current operations that would be phased out by new technology are written like this*, while* planned operations that would be added with new technology are written in this color and underlined.

As a result of electrical issues at the Pershing Square Metro station, there is a complete shutdown of the station, blocking the Red and Purple Lines. Angela, the Red and Purple Line controller receives alarm notifications from her SCADA workstations regarding breakdowns at the Pershing Square Station. Angela uses her SCADA workstation to shut down all tracks to the station. Consequently, a bus bridge must be established.

CREATION AND NOTIFICATION OF BUS BRIDGE- RAIL

SCADA updates rail run info via the transit database (TDB), which in turn causes Nextrip to revise its rail predictions. Updated prediction information is fed from Nextrip to the website, API, Go511, smartphone applications, and social media such as Twitter and Facebook.

Angela uses the rail voice radio system to call all operators on the affected rail lines to announce the bus bridge. Using her ATMS II ROC controller workstation, Angela creates a bus bridge incident. She lists affected lines & stations, and retrieves the bridge route stored in the ATMS II database. ATMS II automatically sends a bus bridge information message using the cellular data network to all affected trains and is displayed on each of the MDTs on the affected trains.

Barney, a rail operator on Red Line train and all other operators on the Red Line and Purple, receives Angela's call and uses the rail voice radio system to repeat verbatim Angela's announcement uses the onboard MDT to send an acknowledgement to Angela via the Metro fleet cellular data network. Using her ATMS II workstation, Angela verifies all affected operators have acknowledged her bus bridge announcement.

Barney then uses his train's PA system to notify his passengers of the curtailed service and provides them information about the bus bridge. ATMS II automatically sends a bus bridge information message using the cellular data network to be display on the onboard LCD monitors for all affected trains and is displayed on each of the MDTs on the affected trains.

Angela uses an Everbridge workstation to type an alert message regarding the bus bridge and notifies social media of the bus bridge. ATMS II automatically sends an alert notification of the bus bridge to the Enhanced Multi-modal Real-time Alerts System which automatically sends alert notifications to be displayed on the appropriate systems including electronic rail station and bus stop signs.

CREATION AND NOTIFICATION OF BUS BRIDGE- BUS

Angela calls contacts Antonio, a controller at the BOC and requests a bus bridge. Antonio, using his ATMS II workstation sees the creation of a bus bridge. Antonio notifies George, the fleet manager, to assign buses for the bus bridge. George assigns buses and documents the buses pulled using his ATMS II workstation enters the buses pulled for bus bridge incident. After George has assigned the buses, he uses the ATMS voice radio system VoIP system, to call the operators of the buses to notify them of their bus bridge assignment. George finds a hardcopy of directions for a the bus bridge routes established for this particular bus bridge and types the bus bridge information in a message to be sent to the operators via the ATMS data radio system. George pulls up the bus bridge information stored in ATMS II database and forwards this instructions to the operators via the Metro fleet cellular data network.

Marjorie, a bus operator with Metro for fifteen years, receives a Bus Bridge message on her MDT listing the pickup location and route for the bus bridge. Her MDT displays a map of the bus bridge route. Marjorie sends an ACKNOWLEDGE message on her MDT screen to indicate receipt of the information. The message is sent to George via the ATMS data radio system via the Metro fleet cellular data network. Antonio and George, sees the acknowledgement by Marjorie and the other operators on their ATMS workstations. Marjorie does not change her headsign display Marjorie logs out of her current assignment and logs back in with a work assignment for this particular bus bridge with changes her headsign display and begins driving to the 7th and Metro Center station to pick up passengers.

MANAGEMENT OF THE BUS BRIDGE

Antonio, the Lead Controller for the bus bridge uses his ATMS workstation to transmit the bus bridge route information via the ATMS data radio system via the Metro fleet cellular data network to all bus road supervisors assigned to the bus bridge. Dwight, a twenty-year veteran Metro Bus Supervisor, receives his bus bridge assignment on his Road supervisor mobile data computer Road Supervisor tablet or portable laptop. Dwight has been assigned to managing the bus bridge for rail passengers exiting the 7th Street/ Metro Center station. Dwight sends an acknowledgement of receipt of the bus bridge message using his Road supervisor mobile data computer Road Supervisor tablet or portable laptop. Dwight proceeds to drive to the 7th Street/ Metro Center station.

Angela, the ROC Controller, uses her ATMS II controller console to send the bus bridge assignment information via the cellular data network to all rail road supervisors assigned to the bus bridge. Robert, a rail field supervisor, receives a radio call from the ROC receives a notification on his supervisor tablet. He has been assigned to the 7th Street / Metro station to manage the bus bridge. He touches ACKNOWLEDGE on his tablet which uses the cellular data network to transmit his acknowledgement back to the ROC, where it is conveyed to Angela on her ATMS II workstation. Robert starts driving to the 7th Street / Metro station.

The buses supporting the bus bridge, transmit their location and passenger load information via the ATMS data radio system every 3 minutes the Metro fleet cellular data network to transmit the information every 30 seconds. Antonio calls each bus supporting the bus bridge manually logs the time and passenger count for each bus bridge trip ATMS II automatically logs the bus bridge information including the bus bridge trip information and passenger loads. ATMS II displays this information and provides arrival predictions of the buses to the BOC and ROC controllers, Road Supervisors and field supervisors, Antonio manages the bus bridge and communicates with bus operators and rail supervisors using the ATMS voice radio system VoIP and the data messages via the ATMS data radio system Metro fleet cellular data network.

Angela, the ROC Controller receives vehicle location information for the Red and Purple trains from her SCADA console. ATMS II receives information from the GPS receivers onboard the trains and beacons on the tracks to provide location information to Angela that is more accurate than from the SCADA for Red and Purple trains. ATMS II also provide passenger counts and sends the data every 30 seconds via the cellular data network to the ROC. Angela, manages the rail related activities for the bus bridge and communicates with rail operators and field supervisors using rail voice radio system and the data messaging functions of ATMS II.

Dwight, the bus supervisor, uses his portable to communicate with Antonio, the BOC Controller, via the ATMS voice radio system VoIP, and uses his tablet to send messages as needed to Angela at the BOC and Robert, the rail field supervisor via the cellular data network. Dwight uses his tablet to view the locations of the buses supporting the bus bridge and the trains arriving at the 7th and Metro station.

Robert, the rail field supervisor uses his portables to communicate with Angela, the ROC Controller, via the rail voice radio system and uses his tablet to send messages as needed to Antonio at the ROC and Dwight, the bus Road Supervisor via the cellular data network. Robert uses his table to view the locations of the trains on the Red and Purple Lines.

PASSENGER INFORMATION

Barney enters a new run assignment on his headsign controller his train's ATMS II MTD, which automatically updates his train's headsigns with the new destination. Before the incident, his train was travelling from Hollywood toward downtown Los Angeles, with its headsign displaying the Red Line terminus of Union Station. Due to the Pershing Square blockage, his headsign now indicates 7th St / Metro Center as his train's end destination. Passengers boarding Barney's train see the headsign showing the train's new final destination so they know they will not directly reach Union Station via this train. When Barney's train reaches the 7th St / Metro Center station, passengers who wish to continue to the Pershing Square, Civic Center / Grand Park, and Union Stations, will need to use the bus bridge.

The Enhanced Multi-modal Real-time Alerts System, receives notification of the bus bridge from ATMS II which in turn automatically sends rail service alert notifications to Metro's website, API, Go511, smartphone applications, and social media such as Twitter and Facebook. The Alert System also sends the rail service alert information to transit passenger information system (TPIS) display signs. During the bus bridge, ATMS II provides the location of buses and trains, their predicted arrival information and passenger loads to Nextrip and website API, Go511, smartphone applications, and social media such as Twitter and Facebook.

Grace, is riding the Red Line from Hollywood on her way to Union Station, when she hears an announcement on the PA system from Barney the rail operator that the Red Line is blocked at Pershing square and so the train will be terminating at the 7th Street / Metro station. Barney states in his voice announcement that a bus bridge has been set up to transport passengers who want to continue to Pershing Square, Grand Park/Civic Center or Union Station. Grace reads detailed information about the bus bridge that is display on the LCD monitor in her train car. The monitor shows the location of the Red Line blockage and a map with clear instructions about where to alight from her train and where to catch her bus bridge bus. Grace, though annoyed about the delay is relieved to see how well-prepared Metro is for this incident. Her train continues to 7th Street / Metro Center station where Grace alights from the train. Grace receives guidance from Robert, the field supervisor who directs the movement of rail passengers out of their trains and up to the street to their bus bridge pickup location. Grace also sees information from ATMS II that is displayed on the rail stations signs.

Grace, who has registered with Metro's website to receive alerts about her commonly used routes, also receives a text message alert on her smartphone notifying her about the bus bridge and providing a url link. She selects the link from her text message and it opens in her smartphone's internet browser, and uses her cellular carrier's data connection in the underground station to access detailed information about the bus bridge and the locations of the buses supporting the bus bridge from Metro's website. She notices another traveler has taken out his laptop and connected to his carrier's Wi-Fi, which is available at the station to access the same information. There are also TPIS signs throughout the station that display information from ATMS II which directs Grace up from the underground station to the bus bridge pickup location. Grace is pleased to see that Marjorie's bus is about to arrive to pick them up.

Grace alights from her bus bridge trip at the Civic Center station. She receives rail departure info for her train to Union Station from the TPIS signs at station and via Metro's website and app.

CANCELLATION OF BUS BRIDGE

Angela, the ROC Controller upon receipt of the alarms from the SCADA system that indicate electrical issues with the Pershing Square station, places telephone calls to the vendors who are responsible for the maintenance of the systems in an alarm state receives notification from the SCADA Message Gateway that the vendors have been automatically notified of the maintenance issue. Angela also relays information to Metro's maintenance staff and if necessary security staff regarding the issues. Maintenance and security staff have direct access to the

SCADA information related to the maintenance issue via the SCADA Maintenance HMI. Mark, who is the field supervisor who is responsible for the management of repair activities at the Pershing Square station, works with the maintenance staff to determine when the station can be reopened.

After the repairs have been completed, Mark notifies Angela, the ROC controller via the rail voice radio system that the station is reopened and service can resume. Angela then uses her SCADA console to revise rail runs to resume normal service. SCADA updates rail run information via the TDB. This prompts Nextrip to update all predictions and transmit them to Metro's website, API, Go511, smartphone applications, and social media such as Twitter and Facebook.

Using the rail voice radio system, Angela calls all operators and supervisors on the Red and Purple Lines using the rail voice radio system announcing resumption of normal service. Angela uses her ATMS II console to send a message to all Red and Purple lines trains of the resumption of normal rail service via the Metro Fleet cellular data network.

Angela uses her ATMS II workstation to cancel the bus bridge incident. She calls Antonio, the BOC controller, that the bus bridge is no longer needed. Antonio also sees the cancellation of the bus bridge on his ATMS II workstation. Angela uses an Everbridge workstation to remove the bus bridge from the Alert System, ATMS II automatically removes the bus bridge alert from the Enhanced Multi-modal Real-time Alerts System causing the alert to be removed from website API, Go511, smartphone applications, and social media such as Twitter and Facebook, as well as from the transit passenger information system (TPIS) display signs.

Barney, a rail operator reads the cancellation message on his MDT and sends an ACKNOWLEDGE. The acknowledgment message is sent over Metro's fleet cellular data network to Angela at the ROC. Barney enters a new rail assignment on the MDT which automatically updates his train's headsign with a new final destination. Barney uses his train's PA to announce the resumption of regular service to the passengers on his train. The cancellation of the bus bridge in ATMS II automatically removes the alert messages regarding the bus bridge.

Angela, the ROC Controller, uses her ATMS II workstation to send a bus bridge cancellation message via the Metro fleet cellular data network to the field supervisors assigned to the bus bridge. Robert, a field supervisor assigned to the bus bridge, receives the cancellation message and acknowledges it on his tablet. The acknowledgement is sent back to Angela at the ROC via the cellular data network. Robert begins directing passengers to wait for trains.

Antonio, the BOC Controller, uses his ATMS workstation to set up a group call via the ATMS voice radio system via VoIP to all of the road supervisors assigned to the bus bridge to announce the bus bridge is ending. He also uses his ATMS workstation to send a bus bridge cancellation message to the Road Supervisors via Metro's fleet cellular data network. Dwight, a Road Supervisor, receives the message on his tablet or portable laptop and sends an ACKNOWLEDGE message via Metro's fleet cellular data network back to Antonio and begins directing passengers who are waiting for a bus to return back down to the 7th and Metro station to board a train. When there are no more passengers waiting for a bus bridge bus, Antonio uses his portable radio and Antonio calls via the ATMS voice radio system via VoIP to let him know that there are no more passengers for the bus bridge. Antonio sends bus bridge cancellation messages to bus operators that are driving to the 7th and Metro station to pick up bus bridge passengers. The bus bridge operators receive the messages on their MDTs, send an ACKNOWLEDGE message to Antonio via the ATMS data radio system via Metro's fleet cellular data network and return back to their divisions.

When the bus bridge is cancelled, ATMS II automatically sends a message to the LCD monitors onboard the trains and on the TPIS monitors at the stations announcing the resumption of normal service on the Red and Purple lines. When the Enhanced Multi-modal Real-time Alerts System

receives the bus bridge cancellation notification from ATMS II, it send an alert notification to passengers who have opted to receive alerts of the bus bridge cancellation.

Appendix B – Metro Bus and Rail Fleet Technology Program Project Descriptions

The following table lists abbreviated names and descriptions for current/planned fleet system projects undertaken by LA Metro. This table is intended to be used in conjunctions with Figures 4 and 5 which provide an overview of existing and planned Metro projects and recommended projects.

ID & NAME	BRIEF DESCRIPTION
CURRENT/PLANNED PROJECTS – IT Systems	
C/P.1 Golden Gate	Metro is/has upgraded their databases that are crucial to many of the current and recommended fleet management systems to Oracle Golden Gate 12C. This version is particularly well suited to real-time data capture and distribution and data integration and replication, all of which is well suited to fleet system needs.
C/P.2 Business Intelligence	Metro has started a Business Intelligence development effort that combines data from a variety of source systems, including many fleet management systems. BI tools would like be expanded or enhanced as recommended fleet management systems come on-board.
C/P.3 Integrated Corridor Management	Metro is undertaking ICM studies and efforts that involve multiple modes in key travel corridors. When implemented ICM facilities would draw upon existing and recommended fleet systems for multi-modal functionality.
C/P.4 Regional Assessment of Transportation Systems Operations	Metro is undertaking regional assessments of transportation systems and these studies may have impacts or recommendations relevant to fleet systems implementations.
C/P.5 DIMS	Metro is in procurement for an integrated video request and distribution management system for bus vehicles, rail vehicles, and fixed facilities. This effort relates to several of the recommended projects that would build upon DIMS as discussed in the plan recommendations.
C/P.6 HASTUS Upgrade	HASTUS is the source of transit schedule and supporting information for existing fleet systems and is anticipated to remain in this role for the foreseeable future. Metro is planning on HASTUS versions upgrades that should be in place in time to support ATMS II.
C/P.7 Real-Time Trip Planner	Metro is upgrading its trip planner to reflect and integrate available real-time information and alerts. Several of the traveler information projects recommended in this Plan could require additional future updates to the trips planner to make full use of Multi-Modal Alerts, Aggregated Real-Time Data, etc.
C/P.8 M3 Architecture	Metro has put out requests for information regarding options for replacing the M3 software platform used for maintenance management and monitoring. M3 has a number of interfaces with existing fleet management systems (including TBD, ATMS, and SCADA). The M3 replacement system should consider the enhanced features, functions, and data available through the recommended projects in the Plan, including ATMS II, Yard Management systems, HMI SCADA projects, etc.
C/P.9 E-Signage	Metro is undertaking a project to promote integration of data from multiple transit providers (e.g. Metro and partner agencies) for electronic

ID & NAME	BRIEF DESCRIPTION
	bus signage at transit stops. This project would be a precursor to the recommended NTCIP compliant signage projects in the Plan.
C/P.10 ESOC Study	Metro recently completed updated studies for the ESOC facility that could support a combined BOC/ROC.
C/P.11Regional ITS Architecture Update	Current and updated regional ITS architecture should review the role of fleet systems and the recommendations of this Plan to ensure on-going consistency.
C/P.12 RIITS Modernization	Metro is planning on updating RIITS which is a user of fleet systems data from ATMS and other sources. The recommended updates to fleet systems in this Plan should continue to provide data to RIITS, and RIITS may ultimately need to be updated over time to take full advantage of additional available data from the new fleet systems.
C/P.13 ESOC Construction	If ESOC moves forward, it may be beneficial to consider the transitions from ATMS to ATMS II and potential coordination with ESOC construction (as well as ultimate plans for BOC and ROC locations).
V.2 Centralized Cloud-Based VSS	Metro is looking into options for cloud-based storage for some security and transit video. This effort could be integrated with DIMS. Additional cloud storage options are included as recommended projects in this Plan.
CURRENT/PLANNED PROJECTS – Bus & Rail Systems	
C/P.22 Bus & Rail ITS Strategic Plan	Metro undertaking a strategic review of bus and rail ITS elements. Any such effort should carefully consider the communications, CAD, on-board architecture and related recommendations in this Plan.
S.1 Standardization of ARINC SCADA (except Green Line)	Metro is updating the SCADA systems for its rail lines except for the Green Line. All of the SCADA systems will utilize the ARINC's SCADA system. The standardization of the Green Line SCADA system will occur during the S.6 project.
C/P.24 Next Generation BSP	Metro is currently studying the next generation of Bus Signal Priority. Outcomes of this study will need to be incorporated into the fleet systems elements supporting BSP in both ATMS II and the on-board architectures.
C/P.25 Platform Track Intrusion Detection System	Metro is undertaking an enhanced intrusion detection system for platform/tracks and tunnels. This system is anticipated to provide alerts that could be integrated with fleet systems including SCADA and/or ATMS II.
AV.5 Dynamic Rideshare Pilot Project	A Connected Vehicle effort by Metro that would represent an early CV project involving coordination of ridesharing and transit usage. Additional general discussion of this and related efforts are included in the Connected Vehicle section of the Plan.
S.6 Standardization of ARINC SCADA (Green Line)	Same as S.1, but for the Green Line.
CURRENT/PLANNED PROJECTS – Communications	

ID & NAME	BRIEF DESCRIPTION
C/P.14 Cellular & LA-RICS Drive Testing	Metro is currently running a single test vehicle to provide preliminary coverage and quality data comparisons between commercial cellular carriers and LA-RICS data networks. Recommendations are to expand this testing effort as part of the recommended communications projects and Connected Fleet Vehicles & Facilities project.
AV.1 LA County DSRC Pilot	Metro is participating in the LA County Dedicated Short Range Communications (DSRC) Pilot project which is a backbone for Connected Vehicle efforts using DSRC in the dedicated 5.9GHz range.
C/P.16	Upgrades to Metro yard WiFi systems for upload/download of video and rail systems data to/from rail vehicles. See also C/P.20 and Y.1 & Y.2 as they are all interrelated depending on funding and implementation timeframes.
CURRENT/PLANNED PROJECTS – On-Board Systems	
C/P.17 Farebox WPA2 Encryption	Metro reviewing potential efforts to enhance farebox/smart card encryption. This could have implications for on-board communications routing through the MGR as recommended in the Plan. This should also be reviewed in conjunction with the Metro Connected Fleet Vehicles & Facilities project.
C/P.18 All Door Boarding Pilot	Pilot effort to review front/rear door simultaneous boardings, particularly in conjunction with TAP use.
C/P.19 ATMS BSP Upgrade	Metro is undertaking efforts to integrate the current Bus Signal Priority (BSP) functionality into the current ATMS system. This would support communications between the IVU and the signalized intersection using 802.11b. This effort should be complete prior to the start of ATMS II.
C/P.20 Connected Fleet Vehicles & Facilities	A core and key element of the recommended on-board architectures in the Plan for bus and rail, the Connected Fleet Vehicles & Facilities project is currently being planned/budgeted by Metro. This would deploy MGRs and cellular data on the entire vehicle fleet (bus and rail). If this project is not accomplished prior to ATMS II, then the final roll-out of these functions would have to be part of ATMS II.
C/P.21 Farebox Near-Real Time Communications	Metro's farebox/TAP groups are reviewing options to support enhanced communications that would reduce the delay between customers initiating or recharging a TAP card and having this change recognized on buses. The transitioning on-board architecture recommends that options for running this communications through the MGR be strongly considered and reviewed, but ultimately the decision will have to be based on more detailed review as part of a specific project effort.
O.6 Planned APC Replacement/Upgrade	Metro has indicated that APCs (automated passenger counters) on some or all buses may be replaced as part of a bus fleet may occur prior to ATMS II roll-out. This would be part of a separate Metro project, but should consider the on-board architecture recommendations as well as ATMS II implementation plans.

ID & NAME	BRIEF DESCRIPTION
T.1 Multi-modal Alerts Pilot	Metro has been undertaking a six month pilot of a real-time alerts system that bridges the gap between the incidents entered and tracked in ATMS and the customer information dissemination systems. It is focused on allowing rapid entry, review, and release of relevant customer service, construction impact, and related alerts to existing and planned Metro information systems. This pilot relates to recommendations for some traveler information projects in this plan, as well as potential functionality for ATMS II.

Appendix C – Key Terms

The following table provides definitions for key terms and acronyms used throughout this Plan.

TERM/ACRONYM	DEFINITION
TERMS	
Long Term	8 to 15 years from the time the Strategic Plan was drafted.
Near Term	5 to 7 years from the time the Strategic Plan was drafted.
ACRONYMS	
ADA	Americans with Disabilities Act
AIM®	ARINC Advanced Information Management
APC	Automated Passenger Counter
API	Application Program Interface
APTA	American Public Transportation Association
ASA	Automated Stop Announcements
ATMS	Advanced Transportation Management System
ATP	Advanced Train Protection
AVA	Automated Voice Annunciation
AVL	Automatic Vehicle Location
BART	Bay Area Rapid Transit
BOC	Bus Operations Center
BOS	Boston (airport ID)
BSP	Bus Signal Priority
CAD	Computer Aided Dispatch
CCTV	Closed Circuit Television
CENTRO	Syracuse NY transit agency
CTA	Chicago Transit Authority
CTS	Cable Transmission System
DIMS	Digital Information Management System
DSRC	Dedicated Short Range Communications
DVR	Digital Video Recording
ESOC	Emergency Services Operations Center
FTE	Full Time Equivalent
GPS	Global Positioning System

TERM/ACRONYM	DEFINITION
GTFS	General Transit Feed Standard
HMI	Human Machine Interface
ICU	On-board video surveillance systems
ITS	Intelligent Transportation Systems
IVU	Intelligent Vehicle Unit
KVM	Keyboard Video Mouse
LA-RICS	Los Angeles Regional Interoperable Communications System
LADOT	Los Angeles Department of Transportation
LAX	Los Angeles airport code
LCD	Liquid Crystal Diode
LMR	Land Mobile Radio
LTE	Long-Term Evolution
MBTA	Massachusetts Bay Transportation Authority
MDT	Mobile Data Terminal
MGR	Mobile Gateway Router
MTC	Metropolitan Transportation Commission (Bay Area, CA)
NFTA	Niagara Frontier Transportation Authority
NICE	Nassau Inter-County Express (Long Island, NY)
NTCIP	National Transportation Communications for ITS Protocol
OEM	Original Equipment Manufacturer
PLC	Programmable Logic Computers (SCADA)
PRTT	Priority Request to Talk
QoS	Quality of Service
RFID	Radio Frequency Identification
RFP	Request for Proposals
ROC	Rail Operations Center
ROM	Rough Order of Magnitude
RSS	Received Signal Strength
RTD	Regional Transportation District (Denver, CO)
RTPI	Real-Time Passenger Information

TERM/ACRONYM	DEFINITION
RTT	Request to Talk
SCADA	Supervisory Control and Data Acquisition system
SEA	Seattle airport code
SFMTA	San Francisco Metropolitan Transportation Authority
SFO	San Francisco airport code
SIL	Safety Integrity Level
SMART	Suburban Mobility Authority for Regional Transportation
SMS	Short Message Service
SORTA	Southern Ohio Regional Transportation Authority
SWOT	Strengths, Weaknesses, Opportunities, Threats
TAP	Transit Access Pass
TDB	To Be Determined
TIS	Traveler Information System
TPIS	Transit Passenger Information System
TSP	Transit Signal Priority
TWC	Track Wayside Circuits
VHM	Vehicle Health Monitoring
VLU	Vehicle Logic Unit
VoIP	Voice over Internet Protocol
VSS	Video Surveillance System
VTA	Valley Transportation Authority
WLAN	Wireless Local Area Network
WMATA	Washington Metropolitan Area Transportation Authority
WRTA	Worcester Regional Transit Authority
WSCA	Western States Contracting Alliance